COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

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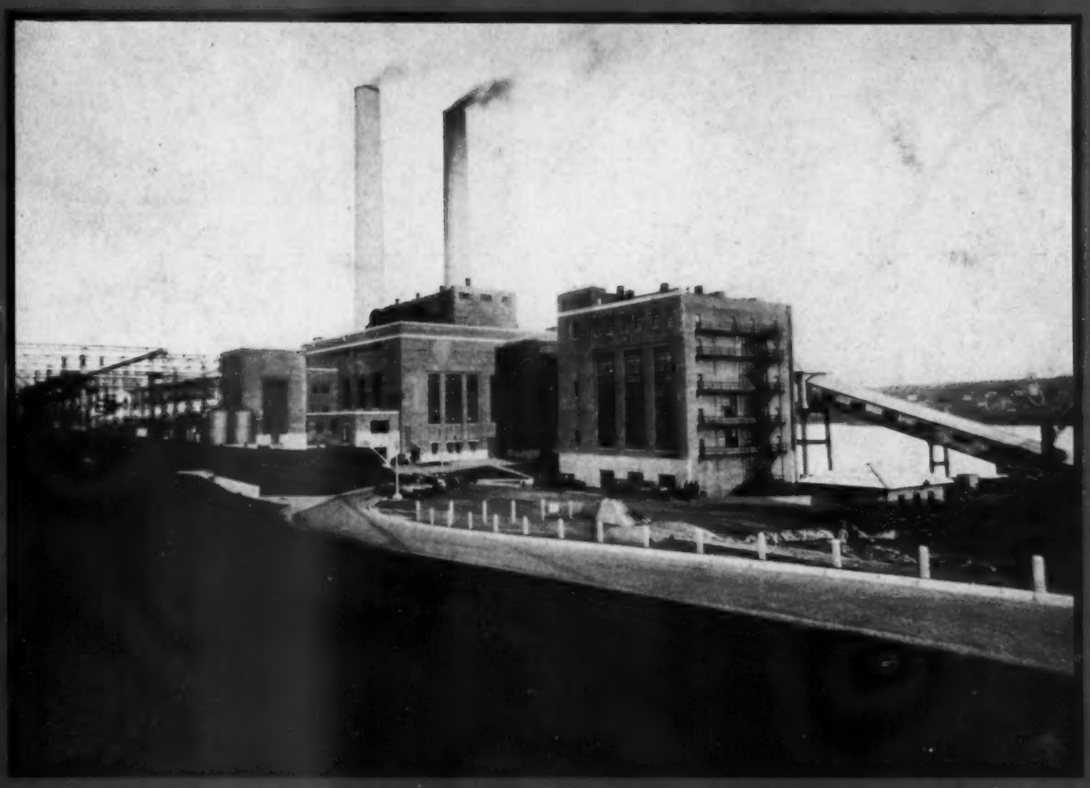
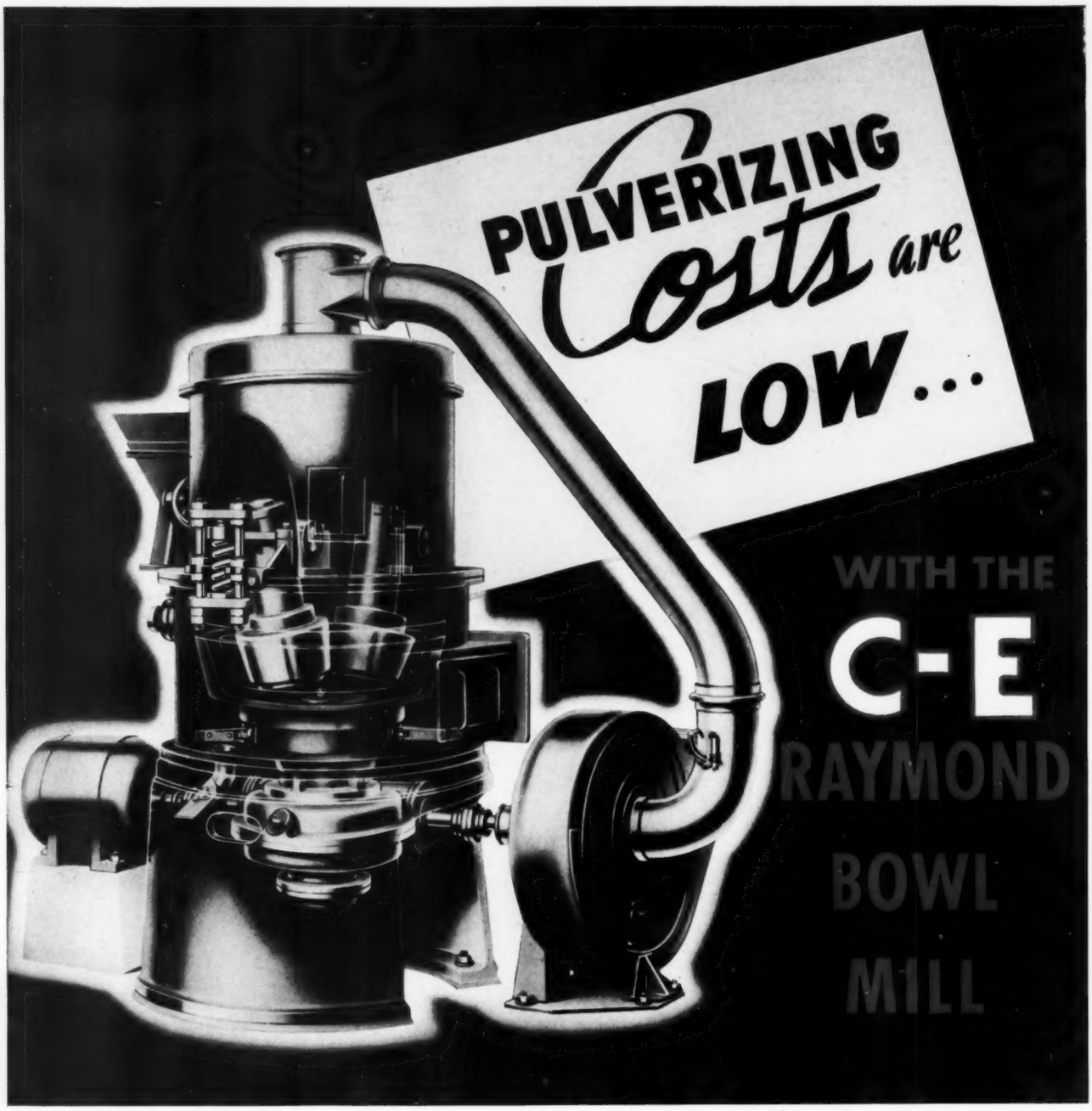


Somerset Station of Montaup Electric Company in which a large forced-circulation steam generating unit will be installed

Factors Affecting Metal Temperature of Furnace and Boiler Tubes

Installation of Thermocouples for Measuring Tube Temperatures

Bituminous Coal Prices Announced



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COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

VOLUME TWELVE NUMBER TWO

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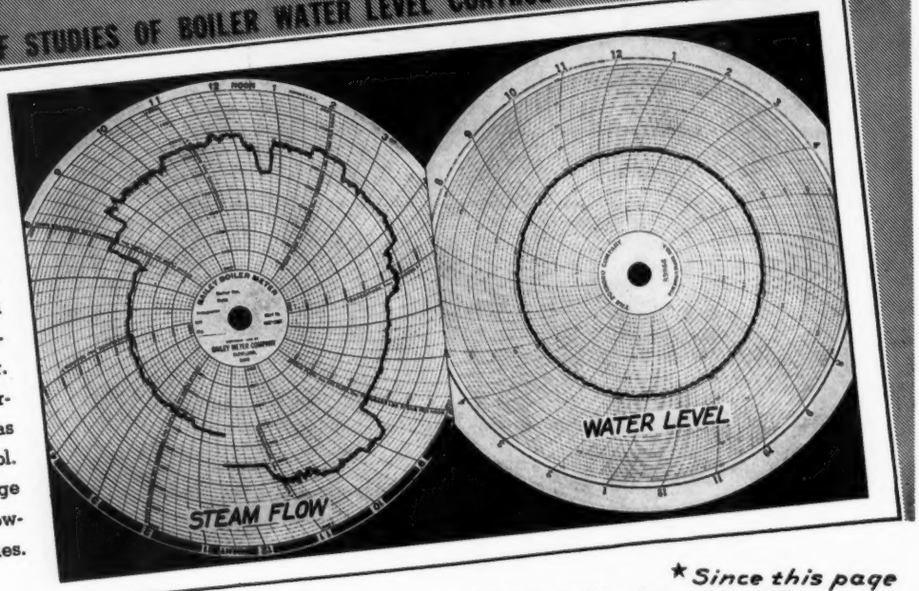

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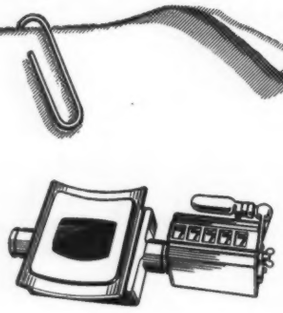

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EDITORIAL

Forced Circulation on a Large Scale

Forced-circulation boilers of various designs have been in service abroad for some years. Continental Europe was the first to employ this type commercially, generally in units of small or medium capacity. More recently, they have found application in England where twenty-five are now reported. The latter range in capacity from 50,000 to 350,000 pounds of steam per hour with pressures from 350 to 2000 pounds and maximum steam temperatures of 940 F. The largest is that installed last year at the Deptford West Power Station of the London Power Company although the pressure in this case is only 350 lb. Two boilers of different design and 250,000 pounds per hour capacity are in operation at the Brimsdown Station of the North Metropolitan Electric Power Company at 2000 pounds pressure, and similar units have been in service for several years in Moscow. Other forced-circulation boilers of large capacity, of the Ramsin type, are said to be operating in Russia, but details are lacking.

While following closely these developments abroad, and not neglecting certain developments in forced circulation at home, American engineers, heretofore, have felt that conditions in this country, which differ in certain respects from those in Europe, were favorable to the continued use of natural circulation for high-capacity steam generating units operating at pressures up to 1500 pounds, and in a few cases higher. Circulation in this range has now been well explored and much experience gained, with the result that knowledge on this score is fairly complete. Meanwhile, much attention has been given to improvements in furnace design, fuel-burning equipment and feedwater conditioning. It may also be said that in the development and use of natural-circulation designs for modern high-pressure, high-temperature steam generating units of large capacity America has outdistanced Europe.

However, it now appears that American engineers are prepared to take another forward step by adapting forced circulation to units of greater capacity than has been attempted abroad, together with the employment of very high pressures and temperatures. The initial move in this direction has been made by the Montaup Electric Company, which generates and supplies power to several New England power companies, in selecting a 650,000-pound per hour, 2000-pound 960 F forced-circulation unit for its station at Somerset, Mass. It is expected that the superposition of this unit, together with a 25,000-kilowatt high-pressure turbine-generator exhausting to the existing 375-pound steam lines, will effect a very marked reduction in the station heat rate and improvement in fuel consumption.

Aside from assuring positive and adequate circulation throughout all elements at this high pressure, the forced-circulation boiler permits greater flexibility in the disposition of heat-absorbing surfaces and in meeting space limitations, while at the same time effecting some saving in weight. These are factors that also commend the forced-circulation boiler to marine service, particularly in naval installations, where it is expected to play an important future rôle.

It is possible that the Somerset installation may mark the beginning of a significant era in American central-station progress.

A Waste of Engineering Talent Among Reserve Officers

Some criticism has been current lately of actions of the military authorities in applying stringent physical requirements to reserve officers in the technical and manufacturing branches of the service. In many cases this has resulted in the rejection or relegation to inactive status of engineers who have long been active and conscientious members of the Reserve Corps and who have qualified through the completion of various courses and details of duty at arsenals or camps. Such cases appear to have little relation to age, aside from the prescribed age limitations for different ranks, but rather involve slight physical defects of sight, hearing, weight, flat feet, etc.; despite the fact that the individuals concerned are performing efficiently in their respective civilian occupations.

Not only have these men patriotically donated their time, involving one to two nights a week, over a period of ten to twenty years, in many cases necessitating the giving up of vacations, but the Government has also been put to considerable expense and effort in their training. Moreover, it has permitted them to continue such training, apparently without regard to these minor defects, leading them to believe that their services would be utilized should an emergency arise. Now that one has arisen much of this work and the sacrifices of these individuals seem to have gone for naught.

It is understandable that the prescribed rigid physical requirements are quite important in the combatant services, but in the non-combatant branches, particularly those involving engineering, it is experience that should be of paramount importance. Unless discretion is used in the application of such rules the military service will be penalized at a time when it most needs specialized experience of engineers in prosecuting the Defense Program. Aside from this, such practice tends to discourage many who otherwise would be anxious to offer their services to the Government.

Installation of Thermocouples

For Measuring Tube Temperatures

By R. M. VanDUZER, Jr.,[1] and R. J. McCAUSEY[2]

The authors point out that the advent of high-pressure high-temperature steam generation makes it important to obtain more accurate tube-temperature determinations because of the reduced safety margin with which the materials operate. The Detroit Edison Company uses chromel-alumel thermocouples because of their good service life and reasonable cost. It is pointed out that in order to obtain consistent accurate results it is necessary to make good connections, to fasten the thermocouples at short intervals and to protect adequately the wire in the hot gas zone to retard its contamination.

IN THE large collection of articles in the technical literature on the subject of high-temperature measurements, very little information is available in the nature of descriptions that give in detail the methods that should be used in the installation of thermocouples such as are necessary to measure properly metal temperatures that occur in boiler and superheater tubes located within high-temperature gas passages. Perhaps the reason for the lack of such information is that there have been relatively few tube failures in boiler units operating at outlet steam temperatures below 750 F. The methods used in determining temperatures in these units, while of doubtful accuracy, have been of value in checking the relative steam distribution and in finding hot tubes. With the advent, in the past few years, of steam temperatures approaching 950 F, the question of more accurate tube-temperature determinations becomes of importance because of the materially reduced safety margin with which tube materials now operate. Almost any type of thermocouple installation will give some indication of tube temperature, but it is only by attention to important details that temperature indications approaching the actual can be obtained.

The procedure followed in the Detroit Edison Company during the past several years in determining tube temperatures has been quite successful in yielding what are believed to be consistent and accurate results. In this work, only chromel-alumel thermocouples were used instead of iron-constantan or noble metal combinations, because they have a good service life compared with other base-metal thermocouples and they are not too costly for general testing work.

As an example of what may be accomplished by proper attention to detail, tube temperatures obtained in one of the 815-lb, 900-F Delray steam-generating units may be cited. Thermocouples were installed on tubes at the superheater outlet header, in a region in which stagnant air is at a temperature of 550 to 600 F, while other thermocouples were installed on corresponding tubes 8 to 10 feet within the gas passage where flue-gas temperatures exceed 2000 F. Temperatures measured outside the gas passage showed steam temperatures in individual tubes, while data from the latter thermocouples indicated tube wall temperatures.

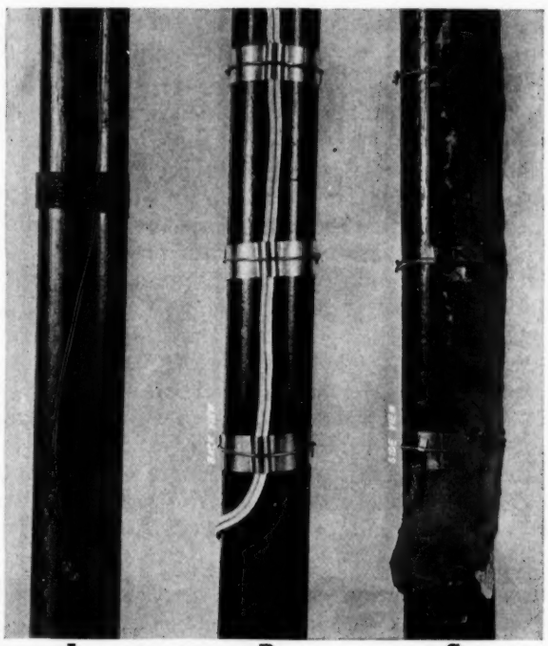

Fig. 1—Thermocouple installation on superheater tube

Measurements gave consistent temperatures 75 to 100 degrees higher on the tubes in the gas space than those

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[2] In Charge of Instrument Division, Research Department, The Detroit Edison Co.

obtained from the tubes outside the gas space. It is probable that with previous methods of thermocouple installation, such as the use of exposed, large-sized wire to withstand the high gas temperatures, a difference of 150 to 200 degrees would have resulted.

It is necessary, in order to obtain consistent results, to pay particular attention to two important details, namely, to fix properly the measuring junction in the tube wall and, second, to protect adequately the thermocouple wires until they pass into a relatively cool zone.

Intimate contact between the thermocouple and the tube at the measuring junction is important. Temperatures shown by the indicating instrument correspond to the emf generated at this point of contact, or, as it is sometimes called, "the hot junction." If the attachment is loose and not in good thermal contact with the tube, erroneous readings will be obtained because the temperature of the measuring junction will not be the same as that of the tube.

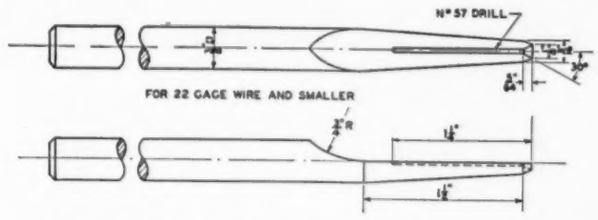

Fig. 2—Peening tool for thermocouple installation

It is of equal importance to protect adequately the thermocouple wires in the high-temperature gas zone to retard, as much as possible, contamination of the wire. Speed of contamination is influenced by two factors; that of temperature and that of atmosphere, both of which can be minimized by adequate protection. If contamination is allowed to progress, the wire becomes nonhomogeneous owing to absorption of and combination with materials in the flue gas, particularly sulphur. When the wire is no longer homogeneous, the temperature-emf relation of the thermocouple is altered by thermal gradients across the nonhomogeneous sections. In the case of boiler and superheater-tube temperature measurements using chromel-alumel thermocouples, if the thermocouple wires leading away from the tube junction can be kept at temperatures below 1200 F and protected from the furnace atmosphere, a service life exceeding six weeks may be expected. During this period reasonably accurate values will be secured.

The technique followed in making the thermocouple installations to obtain boiler and superheater tube temperatures in the Delray steam-generating units will serve to illustrate the precautions necessary to obtain reliable temperature measurements.

Number 22 Awg wire was used in order that the thermocouple wires could be fastened as closely as possible to the tube wall and kept at its corresponding temperature. It is doubtful if heavier wire with larger insulating beads could have been kept at a temperature close to boiler tube temperature, whereas smaller wire would have been too fragile to handle. Ceramic fishspine beads in the smallest size obtainable were used to insulate the thermocouple throughout its length in the gas space.

Holes $^1/_{16}$ in. deep, for insertion of the wire into the superheater tubes, were drilled on the upstream side of the tube using a No. 70 drill. The wires were peened in place and the insulated wires were led directly around the tube to the downstream side and anchored securely with clamps to the tube at 4-in. intervals. The clamps were made from 2 × $^3/_4$ × 0.020-in. Chromel "A" straps and were held in place with No. 14 Chromel "A" wire. The ends of the straps were bent over to prevent the binding wire from slipping and short-circuiting the thermocouple. It has been found essential to fasten the thermocouple at the short intervals mentioned in order to secure proper thermal contact with the tube. The completed thermocouples were then covered with a $^1/_8$-in. layer of Norton's No. 355 alundum cement mixed with five per cent loose asbestos. Water was added to the mixture to bring it to a consistency that would not sag when troweled on a vertical surface. In Fig. 1 are shown views taken of a sample thermocouple in the process of installation. At *A* is shown the peened junction, while at *B* the thermocouple is shown clamped in place prior to covering. The completed installation is shown at *C* in Fig. 1.

The importance of proper fastening of the wire into the tube has been mentioned. The peening tool shown in Fig. 2 has been found more satisfactory than center punches, chisels or other tools for caulking the wire in the hole. These peening tools, when made from a high-speed alloy steel, such as Allegheny LXX, and heat-treated to a hardness of 60 Rockwell C, have given good service on all tube materials.

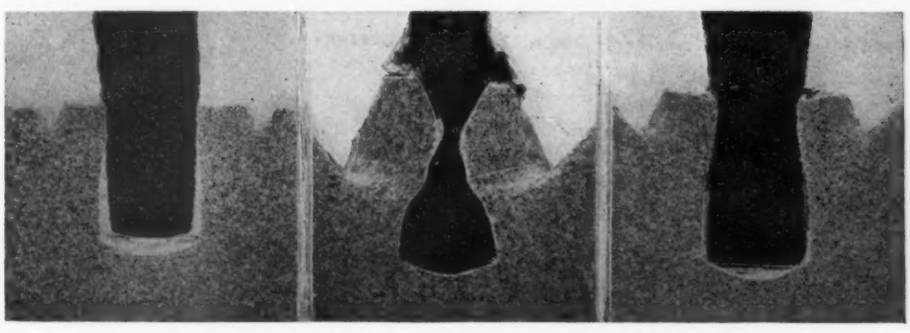

Fig. 3—Enlarged views of thermocouple measuring junction
A—Underpeened B—Overpeened C—Properly peened

In order to secure a good junction, the mechanic, prior to peening the measuring junctions, is required to practice on the same tube material with the same size of wire until a tight joint, in which the wire has not been damaged, is consistently obtained. It is sometimes necessary to overpeen slightly on one side to prevent the wire from turning. Shown in Fig. 3 are several enlarged cross-sections illustrating the results of different peening techniques. At *A* the wire has been underpeened with the attendant possibility of a serious change in electrical contact due to corrosion. An overpeened wire is shown at *B*. The wire has been necked down, in fact nearly cut off, and, in its cold-worked, brittle condition, could be easily broken. A properly peened junction is shown at *C*. Here the wire has been slightly necked down, there is good thermal contact, and there is small chance for scale formation to change the electrical connection between the tube and the wire. It should be noted that the wire ends must be thoroughly cleaned with fine emery to remove scale prior to the peening operation.

Eight thermocouples installed in this manner were examined after six weeks' service and were found to be in excellent condition. The alundum covering was intact and the wire showed no effect of having been overheated or oxidized. This was a good indication that the wire had not undergone more than a slight amount of contamination. Likewise, temperature readings obtained prior to removal were consistent with those obtained during the initial period of temperature measurements.

Another method of protecting the thermocouple from excessive gas temperatures is shown in Fig. 4. Here the problem was to measure the temperature of boiler tubes within the setting and to protect the thermocouples as they were led out of the high-temperature gas zone. It was not possible to adopt the method used for the superheater-tube installations because the boiler tubes terminate in the drum instead of outside the gas passage. The individual thermocouples accordingly were installed on the tubes, strapped securely, protected with the alundum cement mix, and then collected and nested together as shown in Fig. 4, Section *A-A*, between the legs of a hair-pin tube, tack-welded to the boiler tubes and through which cooling water was circulated.

In all, twenty-four No. 22 Awg chromel-alumel thermocouples were installed. The thermocouples remained in service for three months and, at the time of removal, still were giving consistent readings.

The authors do not wish to imply that the methods of thermocouple installation herein described are the only methods that will yield accurate and consistent results in determining superheater and boiler tube temperatures. They do hope, however, that enough emphasis has been placed on the necessity for the proper fastening of the measuring junction in the tube wall and for adequate protection of the thermocouple in high-temperature zones to enable more reliable tube temperature data to be obtained. There also is the added advantage of long life when a proper installation is made. The use in the past of unprotected thermocouples, made from No. 8 or 10 Awg wire, has not only been expensive, but their use has required that all temperature readings be obtained within a few days, and sometimes a few hours, after the boiler unit was placed in service; otherwise, the thermocouples were either burned off or the wire was so contaminated that erratic data resulted.

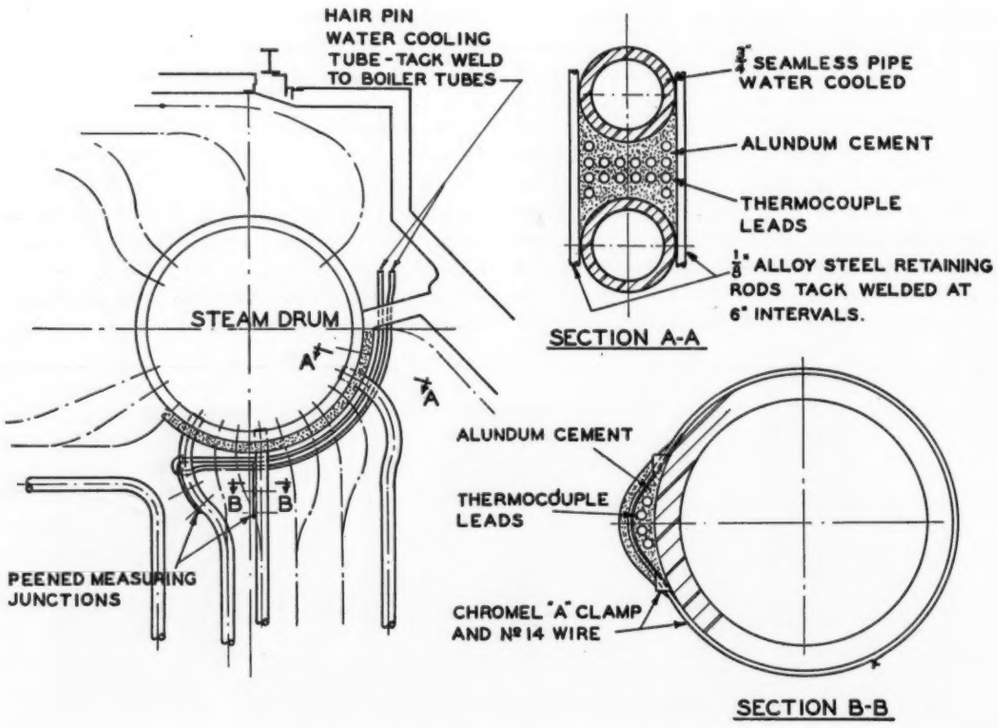

Fig. 4—Boiler tube thermocouple installation

EMBRITTLEMENT DETECTOR

In connection with its extensive researches on intercrystalline cracking, or so-called caustic embrittlement of steel in boilers and fittings, the Eastern Experiment Station of the U. S. Bureau of Mines at College Park, Md., has developed an embrittlement detector which has undergone prolonged tests both in the laboratory and on boilers under service conditions. The following description is taken from a paper by Messrs. Schroeder,[1] Berk[2] and O'Brien[3] at the recent Annual Meeting of the Mechanical Division of the Association of American Railroads at Chicago. In addition to describing the detector and test results, the authors reviewed the causes of such intercrystalline cracking and means for its prevention, with particular reference to locomotive boilers, although applicable also to stationary practice. These are here briefly summarized.

THREE contributing factors in intercrystalline cracking in boilers are (1) leakage that allows concentration of the boiler water, (2) high stress in the boiler metal, and (3) chemical action of the concentrated boiler water on the stressed steel.

In order to obtain a concentration, the leak must be great enough to permit the escape of water vapor to the atmosphere, and small enough so that there will not be a rush of water to prevent concentration in contact with the metal. It may be so small as to be barely detectable by a cold glass or mirror on which the escaping vapor will form a faint haze of condensate, yet if continued over a long period concentrated solutions will build up.

High stress in the boiler metal may be either applied stress or stress which is the result of the manufacturing operations such as cold working, calking, improper riveting and the like.

The chemical action is complex and is probably accelerated in the region of stress. Furthermore, to actually crack the steel the concentrated boiler water must have the correct chemical characteristics to attack the grain boundaries of the metal. That is, it must contain sodium hydroxide and sodium silicate with no inhibitor. A stressed steel specimen placed in direct contact with a very concentrated sodium hydroxide solution, boiling under atmospheric pressure, will suffer intercrystalline cracking. A trace of certain types of silica will sometimes promote attack, and the influence of this compound becomes even more important at temperatures corresponding to 500 lb pressure and above.

Several theories have been advanced to explain intercrystalline cracking in boiler steel. The one that best correlates available information is that based upon a process of selective corrosion.

For example, let Fig. 1 illustrate, at *a* and *b*, the formation of crystal nuclei from a melt of steel. As cooling continues, atoms add to *a* and *b*, producing a crystal form that might be indicated by the dotted lines. These crystals are not, however, in the same orientation. When an atom at *c* is cooled to the point of solidification, it may try to join either one, but in any event will be strongly acted upon by forces from the other, leaving the atom at *c* in a highly strained condition. The work required to remove it from the metal structure may be considerably less than that to remove an atom from the body of the crystal.

Immersing the crystals in a solution with a carefully adjusted corrosive action may remove strained atoms at the grain boundaries while not affecting those in the

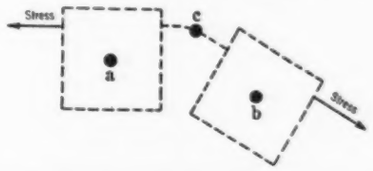

Fig. 1—Strained condition of grain boundary atoms promotes intercrystalline penetration

crystals. This can be done in a simple solution of sodium hydroxide, but if an oxidizing agent or silica is added under the correct conditions it may aid in establishing a protective oxide film on the crystal faces and leave the grain boundaries open to attack. This would further concentrate the chemical action at the boundaries and set up electrochemical activity between the protected face and the exposed boundary to accelerate cracking.

The part played by either internal or applied metal stress, which experiment indicates to be necessary to produce the cracking, is not entirely clear. It may, however, increase the strain and consequently the solution pressure in the atoms at the grain boundaries, or it may help to prevent the formation of an oxide film at this point that would stifle the attack.

Once the crack has started and developed an appreciable notch in the metal, a further accelerating factor appears. The probable reaction producing penetration is:

$$3Fe + 4H_2O = Fe_3O_4 + 4H_2$$

This is accelerated by the sodium hydroxide in high con-

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[2] Assistant Chemist, Eastern Experiment Station, Bureau of Mines.
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centration for it can dissolve and remove the protecting layer of Fe_3O_4 from the metal surface. The Fe_3O_4 that is produced in the notch, however, will occupy a greater volume than the initial Fe and may generate tremendous expansive forces that will cause parting of the metal exactly as a stone may be forced to crack through freezing of water in a crevice.

Embrittlement Detector

The embrittlement detector which has been successfully developed and tested at the Eastern Experiment Station is intended to show whether the boiler water is such as can cause failure by intercrystalline cracking. It can be attached directly to a boiler so that a portion of the water continuously pours into or through it and thus avoids the necessity of sampling with its attendant difficulties and errors.

Fig. 2 shows the essential details of the detector. A groove machined in the base receives this specimen which

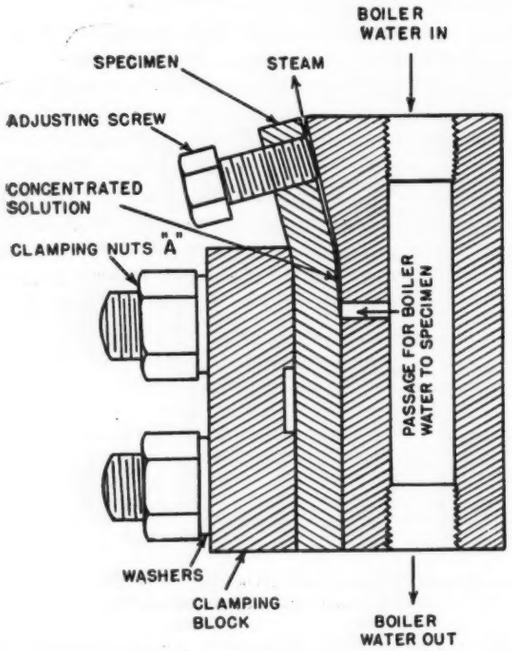


Fig. 2—Embrittlement detector

is held in place by the clamping block and clamping nuts *A*. An adjusting screw enables the investigator to establish the desired leak and at the same time to stress the specimen. The embrittling characteristics of the water make up the third factor under consideration in the test. The feed lines may be fitted with valves to allow the replacement of specimens while the boiler is under full pressure.

Laboratory Testing with the Embrittlement Detector

For laboratory work the detector was attached to an autoclave consisting of the forged steel body of a steam trap which was heated by surrounding it with a large well-insulated electric heater. Tests covering a pressure range from 210 to 1060 lb gage with sodium hydroxide, sodium silicate and sodium chloride in solution resulted in cracking of cold-rolled steel specimens within 20 days. With similar specimens, sodium hydroxide in concentrations of 50 ppm and above cracked the test pieces. Boiler-flange steel withstood concentrations up to 100 ppm. At 250 C (550 lb gage) it appears necessary to have sodium silicate present to cause cracking of hot-rolled boiler-flange steel although little or no silica is necessary at 200 C (210 lb gage). Below this lower temperature a small amount of some of the colloidal sodium silicate solutions added to an alkaline solution containing a little silica will prevent the intercrystalline cracking that would normally occur. Even at this lower temperature, however, there are certain salts common to boilers which will upset the inhibiting action of colloidal silica.

Prevention of Intercrystalline Cracks

From the factors herein discussed and known to be involved in the production of intercrystalline cracks it is evident that elimination of such cracks in new locomotive boilers might be effected by building the boilers in such a manner that they are not susceptible to cracking or to treat the water so that it will not cause cracking in any boiler.

The former suggestion appears better for the new boilers; but it is necessary for the protection of existing boilers to resort to feedwater treatment in spite of the difficulties encountered as a result of varying raw water conditions over a wide geographical range.

A direct construction remedy for the trouble would be to eliminate the seams in which such cracks occur by the use of welded or forged drums. A steel which is resistant to embrittlement would offer another solution.

For treating feedwater to eliminate the embrittlement tendencies there have been several methods suggested. Sodium sulphate is believed by some investigators to inhibit intercrystalline cracking. Laboratory tests show that quebracho and waste sulphite liquor, two organic materials, have a very definite influence in preventing intercrystalline cracks.

Waste sulphite liquor in the amount of 100 ppm in a solution containing 500 ppm of sodium hydroxide did not prevent cracking of hot-rolled steel specimens, but when the concentration was increased to 135 or 200 ppm cracking stopped. (See Table 1.) It must not be concluded that waste sulphite liquor is capable of preventing cracks under all conditions for it did not prevent cracking of cold-rolled steel specimens of approximately the same chemical composition. It has been shown that the action of waste sulphite liquor can be enhanced by the addition of certain other compounds, like sodium aluminate, to prevent cracking even in the cold-rolled steel specimens.

TABLE 1—TESTS IN THE EMBRITTLEMENT DETECTOR WITH WASTE SULPHITE LIQUOR

Specimens of Hot-rolled Boiler Flange Steel
Test Temperature 200 C (210 gage). Air Evacuated for All Tests

Test No.	Solution Composition in Ppm NaOH	Na_2SiO_3	NaCl	W.S.L.*	Length of Test-Days	Test Result
97	500	100	20	100	30	Cracked
136	500	100	20	135	30	No cracks
73	500	100	20	200	28	No cracks
162	500	100	20	200	30	No cracks
182	1000	100	200	300	31	No cracks

* Waste Sulphite Liquor—amount added in the form of a solution containing approximately 50 per cent solid.

The protective action of waste sulphite liquor is reduced or destroyed by the presence of high concentrations of sodium sulphate and sodium chloride. (See Table 2.) Studies are now going on to show that the detri-

mental effects of the sulphate and chloride can be nullified. Embrittlement cracking can be reduced or eliminated if the concentration of sodium hydroxide is kept low enough but great care should be taken to see that the concentration is not so low as to permit corrosion and pitting.

Any feedwater treatment used to prevent embrittlement cracking must be under continuous control. The use of waste sulphite liquor is not recommended without chemical control of the concentration in the boiler water or without use of the embrittlement detector to insure adequate treatment.

TABLE 2—EFFECT OF SODIUM SULPHATE AND SODIUM CHLORIDE ON THE PROTECTIVE ACTION OF WASTE SULPHITE LIQUOR

Specimens of Hot-rolled Boiler Flange Steel
Test Temperature 200 C (210 gage). Air Evacuated for All Tests

Test No.	Solution Composition in Ppm NaOH	Na_2SiO_3	NaCl	Na_2SO_4	$Na_2Al_2O_4$	W.S.L.*	Length of Test-Days	Test Result
235	500	100	20	1000	..	200	30	Cracked
254	500	100	400	1200	..	200	30	Cracked
269	500	100	500	2000	20	200	23	Cracked
304	500	100	1000	2000	50	300	22	Cracked

* Waste Sulphite Liquor—amount added in the form of a solution containing 50 per cent solid.

Laboratory and statistical evidence now indicate that both stationary and locomotive boilers may be operated with embrittling waters without suffering cracking. As a result the following statement appears justified: If sodium sulphate or other agent is maintained in a boiler water and that boiler does not suffer cracking, it cannot therefore be concluded that the water contained a protecting substance, for the boiler may have been so constructed that it would not have cracked in the absence of such compounds.

A.S.M.E. Fall Meeting at Spokane

The Fall Meeting of the American Society of Mechanical Engineers will be held at Spokane, Wash., September 3 to 6, with headquarters at the Davenport Hotel. A variety of papers of general interest will be presented, a number of which have particular reference to the Northwest and to scheduled inspection trips. Among the latter are several pertaining to the Grand Coulee Dam and power project. These include, "Cooling the Concrete of Grand Coulee Dam," by Clarence Rawhauser; "Design and Technical Aspects of a Frozen Earth Dam at Grand Coulee," by Lloyd V. Froage; "Turbines for Grand Coulee Dam," by J. J. Burnard; "Testing Pumps for Grand Coulee Dam," by R. T. Knapp; "Control Gates at Grand Coulee Dam," by P. A. Kinzie; "Penstocks for the Grand Coulee Dam," by P. J. Bier; "Transportation and Handling Equipment for the Placing of Concrete at Grand Coulee Dam," by Ray Fullerton; and "Grand Coulee and Electrometallurgical Industries," by A. E. Drucker.

Among the other papers will be "Coal Resources of Washington," by Joseph Daniels; "Burning Characteristics of Washington Coals in the Domestic Stoker," by H. F. Yancey, K. A. Johnson and J. B. Cordiner, Jr.; "Combustion of Waste-Wood Products," by H. W. Beecher and Robert D. Watt; "Effect of the Guffey Bill on Fuel Problems in the Pacific Northwest," by D. S. Hanley; "The Future of Power Use in the Pacific Northwest," by H. V. Carpenter; and "Northwest Power and Electro Industries," by W. C. McIndoe. There will also be several papers dealing with various aspects of the lumber industry of that region.

The program includes a banquet, several luncheons and numerous inspection trips, particularly an all-day visit to the Grand Coulee Development. A special A.S.M.E. tour has been arranged for members attending from the East. The group will leave New York on August 25 and return September 13, visiting en route several National Parks.

Large Forced-Circulation Boiler for Somerset Station

An order has recently been placed with Combustion Engineering Company for the first high-capacity, high-pressure, forced-circulation steam generating unit to be installed in this country. It will go into the Somerset Station of the Montaup Electric Company which generates and distributes electricity to a number of New England power companies.

The unit is designed for an output of 650,000 lb of steam per hour at 2000 lb pressure and 960 F total steam temperature. It will serve a new G.E. 25,000-kw topping turbine-generator exhausting to the existing 375-lb station mains which supply two low-pressure turbine units now in use in the plant and will produce an additional 47,000 kw. Steam for the latter is now furnished by five low-pressure boilers each of which occupies a floor space equivalent to that required for the new high-pressure boiler. After exhausting from the topping turbine at around 400 lb the steam is returned to the high-pressure boiler for reheating to 750 F, before passing to the low-pressure turbines. It is anticipated that the topping installation will effect a large reduction in the station heat rate.

The new unit will be tangentially fired for burning either pulverized coal from the existing storage system or for burning oil as an alternate fuel. A completely water-cooled furnace of the slagging-bottom type is provided.

Included in the unit are a convection-type superheater, reheater, economizers and regenerative type air preheaters. The superheater is laid out for a practically constant steam temperature from full load down to 480,000 lb per hr.

There will be three circulating pumps, one motor driven, one turbine driven and one with dual drive, any two of which will provide circulation for all load conditions. The feed pumps take feedwater at 475 lb suction pressure and deliver at 2200 lb.

In natural-circulation boilers, which heretofore have been used exclusively in the power stations of this country, circulation is dependent upon the varying densities of the water and water-steam mixtures at different temperatures. For high steam pressures this involves placing the drums at considerable height in order to provide the necessary hydraulic head to assure circulation. On the other hand, the forced-circulation design insures positive circulation, independent of the load, allows flexibility and compactness in the arrangement of the heating surfaces and permits the steam drum to be placed in any convenient location.

The adoption of this type of unit at the Somerset Station marks the beginning of a new epoch in high-pressure steam generation in this country.

A.S.T.M. Papers Discuss Creep

FIVE technical papers on the effect of temperature on the properties of metals, with particular reference to creep, featured one of the sessions of the A.S.T.M. Annual Meeting at Atlantic City on June 24 to 28.

E. L. Robinson, Turbine Engineering Dept., General Electric Co., discussed "High Temperature Rupture and Creep Tests." Consideration of these test results, the author stated, leads to several questions difficult to answer without years of actual service including service severe enough to indicate what type of distress must be expected. It seems plain that materials put their best foot forward and hang together better for a year or two than for much longer periods of time.

Actually when treatments are varied the rupture strength is affected much less than the creep strength. Thus if working stresses are set with reference to a low creep strength material, the rupture strength may be four times the working stress. On the other hand, if the treatment is varied to improve the creep strength, the rupture strength may turn out to be no more than double the nominal creep strength and some tests show the margin to disappear entirely.

Where the amount of creep is not in itself an important consideration, there is good reason for design to be guided by rupture strength rather than by creep strength. On the other hand, where the amount of extension, distortion or deflection is of prime importance, both creep strength and rupture strength must be considered.

Extensive data on "The Creep Strength of 17 Low-Alloy Steels at 1000 F" were reported by **R. F. Miller** and **W. G. Benz,** Research Laboratory, U. S. Steel Corp. and **W. E. Unverzagt,** Metallographist, National Tube Co. The creep strength of carbon-molybdenum steels increases with increasing molybdenum content both in the normalized and in the normalized and tempered condition. In each composition the creep strength of the normalized material is higher than that of the normalized and tempered material. At 1000 F the pearlitic structure resulting from the normalizing treatment is more unstable than the spheroidized structure resulting from normalizing and tempering.

The addition of chromium tends to lower the creep strength of carbon-molybdenum steel, but this decrease may be partially offset by increasing the molybdenum content. The stability of the carbon-molybdenum steels is increased by the addition of chromium.

Titanium or columbium improves the creep strength of chromium-molybdenum steels but silicon and aluminum affect their creep strength adversely.

Referring to a table providing creep strength of some of the steels which the authors investigated, they concluded that if the analyses of the steels alluded to were within the range given by the A.S.T.M. specifications, and if the heat treatment and grain size of the steels were known and reproducible, it would now be possible to correlate creep test data obtained in different laboratories within 2000 lb per sq in.

The effects of composition and heat treatment on the high-temperature rupture properties of ferrous alloys were discussed by **R. H. Thielemann,** Research Laboratory, General Electric Co. He indicated that from sustained load rupture tests on various ferrous alloys at elevated temperatures both transcrystalline and intergranular fractures are encountered. Transcrystalline fractures are characterized by the ductile, necked-down appearance of the broken test specimens. In contrast, intergranular fractures are marked by their lack of ductility and brittle appearance.

The susceptibility of the various alloys to failure by intergranular cracking varies with the type of the alloy as determined by its composition. Only the chromium-bearing ferritic alloys did not show evidence of intergranular cracking in tests of long duration. With the nickel-chromium austenitic alloys, brittle intergranular fractures are encountered even in tests of only a few hours' duration. The rupture properties of those alloys which will respond to heat treatment can be varied by altering the structures within the grains.

As with the creep strength, the effect of increasing the grain size of an originally fine-grained alloy is to increase its rupture strength.

A paper on "Study of Effects of Variables on the Creep Resistance of Steels" by **H. C. Cross** and **J. G. Lowther,** of Battelle Memorial Institute, described results of creep tests at 850 F on two pure irons, one with 0.5 per cent silicon added, on steel from rimmed and silicon-killed ingots from the same heat (0.06 to 0.08 per cent carbon), and on a rimmed steel (0.16 to 0.26 per cent carbon) and four different killed steels with 0.14 to 0.17 per cent carbon. All the materials were heat-treated to produce similar fine- and coarse-grained structures for comparison of their relative creep resistance and to determine the effect of different deoxidation practices.

Heat treatment producing coarsening of a practically carbon-free pure iron and pure iron containing 0.5 per cent silicon improved the creep resistance. Silicon-killed steel showed consistently better creep resistance than rimmed steel as heat-treated to produce both fine- and coarse-grained material. In S.A.E. 1015 steels, silicon-killed steels are superior to silicon-aluminum and aluminum-killed steels as fine-grained or as slow-cooled from the coarsening treatment used, while as air-cooled from the coarsening temperature the steels showed similar creep resistance.

A high-speed tension test machine was discussed by **M. Manjoine** and **A. Nadai,** Research Laboratories, Westinghouse Electric and Mfg. Co., with discussions of the use of the machine at high temperatures. Stress-strain curves were automatically recorded on the screen of a cathode-ray oscillograph, using the elastic strain in a very rigid steel bar as a means for the indication of the load and the relative movement of the heads of the specimens for determining the strains. While the authors are carrying out further work, they state in their paper, "From the evidence available it seems that the trend of the curve representing the general speed law of plastic deformation at a given temperature is characterized by an inclined straight line in the semi-logarithmic plot at the intermediate range of speeds."

Low-Cost Flue-Dust Sampler

The accompanying sketch[1] shows a simple and low-cost flue-dust sampler developed and used effectively in connection with the atmospheric pollution survey conducted by the WPA in Chicago. It consists of pitot tubes to measure gas velocity in the breeching; sampling nozzles; a separating device made of milk bottles, glass tubing and rubber hose; an orifice meter; water and mercury manometers; thermometers; and vacuum pumps or aspirators.

The flue-dust sample is drawn through the sampling nozzle in the breeching and passes to the impinger bottles which retain the solids in water while allowing the gas to pass through to the aspirator. The sampling nozzle used generally in the Chicago survey was 0.657 in. diameter, although smaller nozzles are required for high velocity cases and larger nozzles to get an adequate sample when the velocity in the breeching is low. In all cases the gas velocity in the sampling tube is maintained equal to that in the breeching.

Each impinging bottle is fitted with two glass tubes, the inlet tube extending down to within half an inch of the bottom and the outlet tube being connected by rubber tubing to the inlet tube of the next bottle. The first five bottles are filled to a depth of 3 in. with distilled water and the sixth bottle contains no liquid. The separating effect depends, in part, on the high-velocity impact and the washing action of the water and, in part, on the wetting effect of the vapor above the liquid level. Measurement of the amount of gas sampled is effected by a manometer across the orifice and a mercury U-tube reading inches of mercury upstream of the orifice. Temperatures of the gas in the breeching and at the orifice are also taken. A drip jar at the outlet of the exhausting device catches any dust that is not entrapped in the bottles and thus indicates to the operator that the equipment is not functioning properly.

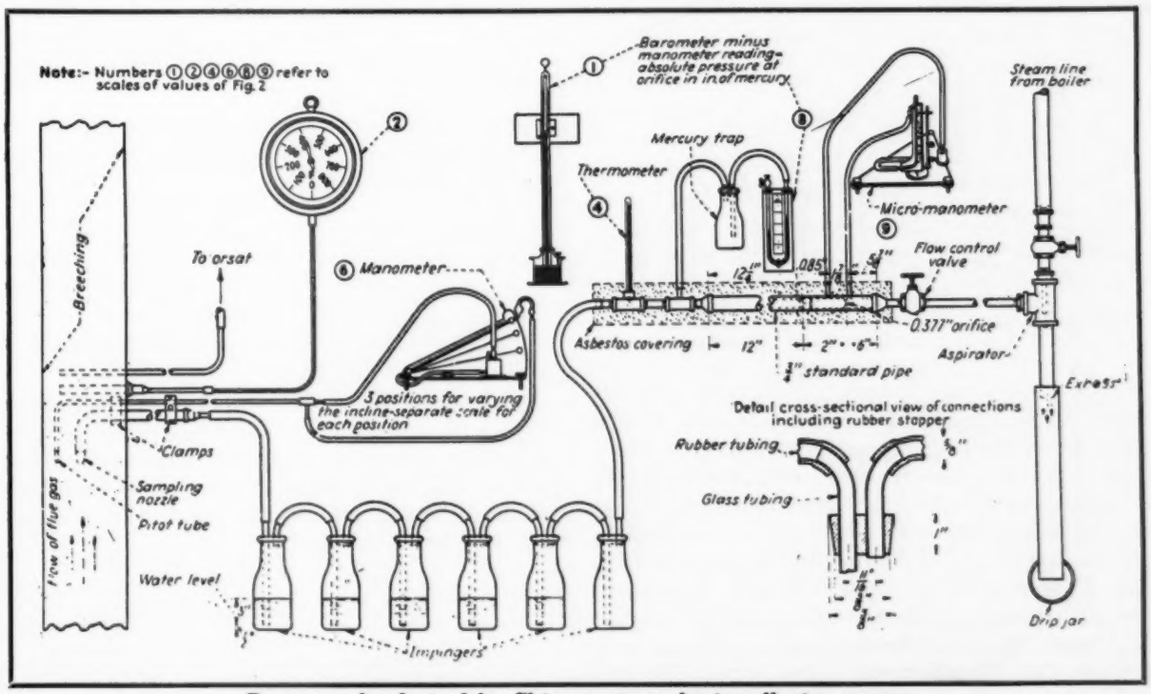
[1] Reproduced from the Smoke Prevention Association of America's 1940 "Manual of Ordinances and Requirements."

In the application of this device the location of the sampling point is important. More accurate readings are attainable from samples taken in vertical ducts or breechings because of the tendency of the dust to settle in horizontal runs. Where necessary to sample in horizontal breechings, crosswise vertical baffles were inserted to dam the drift of settled dust.

Before starting a test, the net cross-sectional area of the breeching or stack is divided into zones of approximately equal area so that a single sampler can be moved from center to center of these zones for an equal period. This is in accordance with the A.S.M.E. Tentative Test Code for Dust Collecting.

When wide ranges of firing conditions or gas flow exist, the accuracy of the sampling procedure is increased by reducing the duration of the sampling interval and increasing the number of complete transverses of the breeching cross-section. In traversing the stations, the sampling velocity is varied to correspond with the velocity in the duct at each point so that the dust collected during an entire run represents a weighted average. To hold the sampling velocity equal to that in the breeching at the point of sampling requires measurement of five quantities, namely, (1) velocity pressure by the pitot tube at the sampling point, (2) the barometer reading, (3) temperature of the gas at the orifice, (4) temperature of the gas in the breeching, and (5) the absolute pressure immediately upstream from the orifice. A convenient chart has been prepared to determine the velocities readily.

It is pointed out that in passing combustion gases containing entrained fly ash through water any sulphur dioxide present will react with the oxides of alkaline earths and alkalis in the ash. This will cause an increase in the weight of dust indicated. However, this increase is compensated by the fact that all collectors have an efficiency less than 100 per cent. The device is said to collect more than 90 per cent of the dust that enters the sampling nozzle.



Dust sampler devised for Chicago atmospheric pollution survey

Factors Affecting Metal Temperature of Furnace and Boiler Tubes

By **W. S. PATTERSON**
Combustion Engineering Company, Inc.

Boilers have been progressively designed for higher pressures, higher steam temperatures and greater capacity in a given space. To accomplish this, progressively higher heat absorption rates have been necessary until, today, in some boilers, all the heat required to evaporate the water into steam is received directly from the burning fuel in the combustion chamber, and only the superheater, economizer and air heater operate on the convection principle. But in spite of this, frequent failure of the steam generating tubes is not common although there is sometimes a mystery attached to certain failures. It is hoped that the discussion and conclusions of this article will prove that the reasons for most tube failures need not be clouded in mystery, particularly if the tubes are "clouded" with boiler scale.

THE hot surface temperature of furnace and boiler steam generating tubes is affected by the following factors: (1) operating pressure, (2) total heat transfer, (3) metal thickness, (4) metal conductivity, (5) presence of internal scale, (6) conductivity of internal scale, (7) thickness of internal scale, (8) presence of steam pockets, (9) thickness and velocity of steam in the pocket, and (10) heat transfer coefficient through evaporating film.

The temperature gradient for one particular set of operating conditions involving some of the factors enumerated above may be illustrated as shown in Fig. 1. Obviously, t_1, the temperature of steam and water in the tube, may be calculated with sufficient accuracy from the Steam Tables using the boiler drum operating pressure plus the calculated head of water above the point in question. This temperature will vary as shown in Fig. 2, but regardless of pressure it does not closely approach the oxidation temperature of steel because 705.4 F is the saturation temperature at critical pressure.

We are, therefore, primarily interested in studying the factors which further affect the gradient between t_1 and the hot face temperature of the tube, t_4. It is apparent that the heat given up by the furnace gases, and which results in the generation of steam within the tube, must pass through the series resistances interposed by: (1) gas film, (2) furnace slag, (3) tube wall, (4) internal scale, (5) evaporating film. Furthermore, if the furnace slag and internal scale are not securely bonded to the metal of the tube, two additional resistances may be added: (6) gas film between slag and tube, and (7) steam film between internal scale and tube. Heat transfer through the gas film (1) and evaporating film (5) does not follow the simple equation for conduction; but for the other resistances, including (6) and (7), the temperature gradient through each is inversely proportional to the thermal conductivity. For the simple case of conductance through a body having flat parallel plane surfaces, equation (1) may be used:

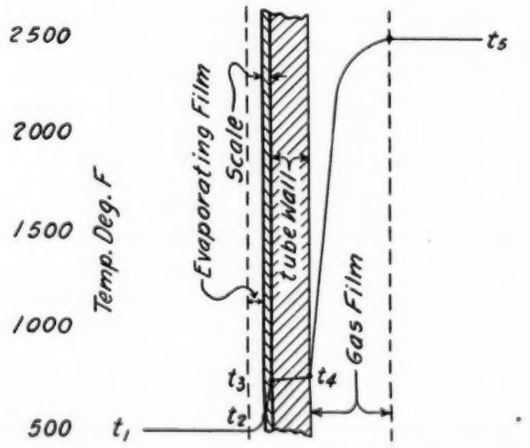


Fig. 1—Temperature gradient at furnace tube wall

$$\Delta t = \frac{Qh}{k} \qquad (1)$$

where Δt = temperature drop across any single resistance, deg F
Q = heat absorption, Btu/sq ft/hr
h = thickness of resistance, ft
k = thermal conductivity, Btu/sq ft/hr/deg F for 1 ft thickness

For the case of a tube, the surfaces are curved and the heat transfer surface area decreases as the center is approached. Therefore, for radial heat flow equation (1) must be modified to allow for the differences between inside and outside radius of curvature of the surfaces, as indicated by equation (2):

$$\Delta T = \frac{Q}{12k} r_2 \left(\log_e \frac{r_2}{r_1}\right) \qquad (2)$$

where r_2 = outside radius, inches
r_1 = inside radius, inches
Q = Btu/sq ft/hr of outside tube surface
other terms as in equation (1).

In the foregoing equation, Q is heat absorption per sq ft of *outside* surface. Therefore, in the case of a tube uniformly heated around its entire circumference, Q is continually increasing as the center of the tube is approached, even though the heat flow, Btu per hr, through any sector is constant at any distance from the center.

A tube receiving radiant heat from the furnace is a special case, and the most important case in modern boilers. Such a tube receives less heat on the side away from the furnace; in fact, in the case of a furnace wall

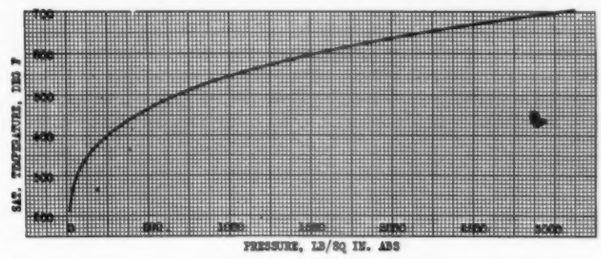


Fig. 2—Saturation temperature corresponding to various operating pressures

tube, it may receive a negligible amount from the wall side. There seems to be evidence also that even on the side of the tube facing the furnace, heat absorption and hot face temperature are not uniform. Therefore, until more is known about the heat distribution after it passes into the tube, it is difficult in such a case to calculate heat distribution at the interior evaporating surface. Obviously, however, with only one-half the circumference receiving heat, the thickness of the tube is so small compared to the circumferential distance to the back of the tube that more heat will pass through the metal of the furnace side. A condition of equilibrium is reached which depends on the tube thickness, the presence of scale or slag, and, of course, on the distribution and intensity of heat on the furnace face.

It may be concluded, however, that in a furnace wall tube, the hot face temperature is greatest on the furnace side, the evaporation from the inside surface is greatest toward the furnace side, and, for the purpose of investigating dangerous tube metal temperatures, it is only necessary to investigate a unit section at the area of most intense heat absorption. It will, therefore, be assumed for the purpose of this study that flow of heat in any segment is radial. In the case of a finned furnace tube, nearly all the heat received by the fins probably goes to the back half of the tube, but the heat intensity at a unit section of the front face of the tube proper may be determined by expressing the heat absorption rate in terms of the projected area.

The total heat absorption by the projected surface exposed to radiant heat has been measured in many furnaces, and, if all the walls of these furnaces were perfectly clean, it would be possible to calculate the *average* heat absorption rate per unit area of wall. But if, due to slag, the surface is only half as effective as clean surfaces would be, then the error in the heat absorption rate per unit area, due to using the entire projected wall area, would be wholly on the low side. Or, if the heat absorption has an intensity in some sections which is twice the measured and calculated average, then obviously the test average should not be used for investigating maximum metal temperature.

However, from the basic equation of radiant heat absorption, we can investigate what absorption rate might be expected under various conditions of furnace and tube temperature. Equation (3) may be used for this purpose for a water-cooled furnace.

$$Q = \frac{H}{A} = 0.172E\left(\frac{T_5^4}{100} - \frac{T_4^4}{100}\right) \qquad (3)$$

where Q = rate of radiant heat absorption at cold surface, Btu/sq ft/hr
A = effective projected radiant surface, sq ft
H = total heat given up by flame, Btu/hr
E = combined emissivity of cold surface and flame
T_5 = absolute flame temperature corresponding to t_5 in Fig. 1
T_4 = absolute cold surface temperature corresponding to t_4 in Fig. 1

The emissivity of an oxidized steel surface will approach unity at high temperatures and may be assumed to be 0.95 for a boiler furnace. The flame emissivity depends on many factors, such as: luminosity, nonluminous radiating constituents, volume and temperature. For a pulverized fuel flame, 0.70 would be a reasonable value, and for combined emissivity we will use 0.65 as a reasonable value. Fig. 3 is plotted from the above equation using a value of $E = 1$ so that for any other value of E, the radiant heat absorption may be readily determined by multiplying the ordinate reading by the correct E value. It will also be noted that, except for very low furnace temperatures, a large variation in the cold surface temperature has very little effect on absorption

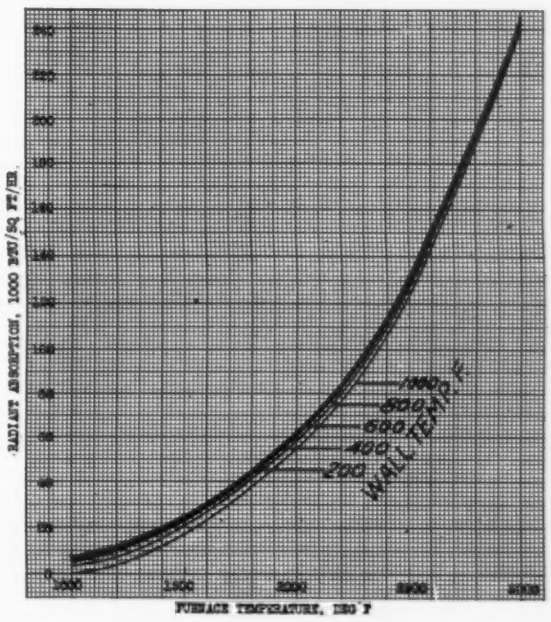


Fig. 3—Radiant heat absorption vs. furnace temperature, showing effect of furnace wall temperature (plotted from equation (3) using E = 1)

rate. For example, the absorption rate decrease for an increase in tube temperature (t_4) from 600 to 800 F is only 1 per cent for 3000 F and 1.5 per cent for 2500 F furnace temperature (t_5).

Although many tests have been conducted in which the furnace leaving temperature has been measured, fewer data are available on measurements of maximum furnace temperature. One reference (a) gives measurements in a dry bottom furnace and reports a maximum of 2600 F.

Obviously, the maximum temperature in many slag-bottom furnaces is higher than this because coals with ash-fusion temperature (fluid state) as high as 3000 F have been used with success. Using this temperature in equation (3) or Fig. 3 and multiplying by an emissivity factor of 0.65, it will be noted that an absorption rate of 150,000 Btu per sq ft per hr might reasonably be expected on a limited portion of the furnace wall area.

The measured temperatures reported at various elevations in the furnace mentioned in the above reference (a) are indicated by the points on Curve *A*, Fig. 4.

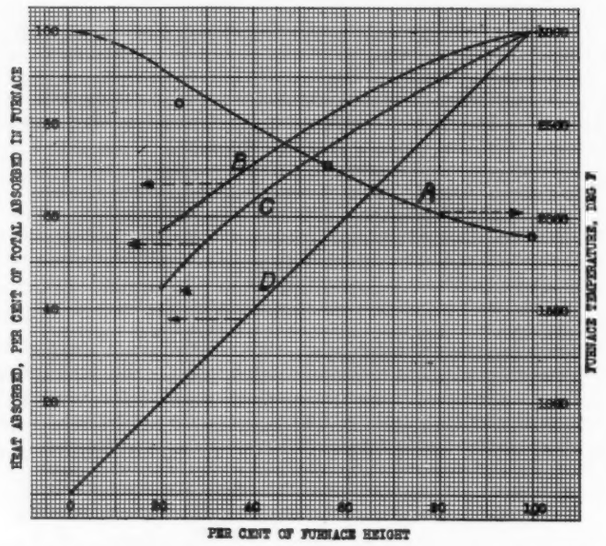


Fig. 4—Typical flame temperature gradient in water-cooled furnace and heat absorption relationships

Curve *A:* Flame temperature gradient
Curve *B:* Heat absorption calculated from temperature gradient
Curve *C:* Probable heat absorption below point of temperature measurement
Curve *D:* Curve for uniform heat absorption

They were taken on a tangentially-fired dry-bottom furnace but the upper end of Curve *A* deviates from the data to show what might be expected on a wet-bottom furnace. Curve *B* is plotted from Curve *A* and indicates that, of the total heat absorbed by the furnace walls, more than 50 per cent has been absorbed by the time the gases have reached an elevation corresponding to 20 per cent of the distance from floor to furnace roof. But this does not mean that over 50 per cent of the furnace absorption takes place in the first 20 per cent of the surface, because some of the heat absorption, which resulted in reducing the temperature to the value measured at this elevation, was absorbed by surface exposed to radiation above the point of measurement. Therefore, Curve *C* would, in the writer's judgment, represent a reasonable estimate of the percentage of the heat absorbed by the furnace which is absorbed by the surface below various heights above the floor.

The equation of Curve *C* within the limits for which it is drawn may be written:

$$X_1 = 10\sqrt{l_1} \qquad (4)$$

where l_1 = distance from floor, per cent of furnace height
X_1 = heat absorbed in distance l_1 as per cent of total heat absorbed by furnace

Curve D represents the other extreme of uniform absorption from bottom to top of furnace.

Numerous tests have been conducted on large completely water-cooled tangentially-fired units on which an *average* absorption rate per sq ft of effective projected radiant surface of 70,000 Btu per hr or better has been obtained. Using this average and Curve *C* from Fig. 4, we may then predict what the probable intensity of absorption will be in various parts of the furnace. This has been plotted in Fig. 5 for increments of 20 per cent, and the continuous step curve gives the average intensity of absorption for the five increments of surface, whereas each of the horizontal lines *A*, *B*, *C*, *D* and *E* gives the cumulative averages. It is interesting to note that this method of predicting a probable maximum heat absorption rate produces a result almost identical to that independently arrived at by the use of equation (3) and a consideration of probable furnace temperature in the zone of most intense combustion.

The thickness of tube metal required for a given pressure varies with the tube diameter and allowable stress of the metal. It is common practice to use mostly low-

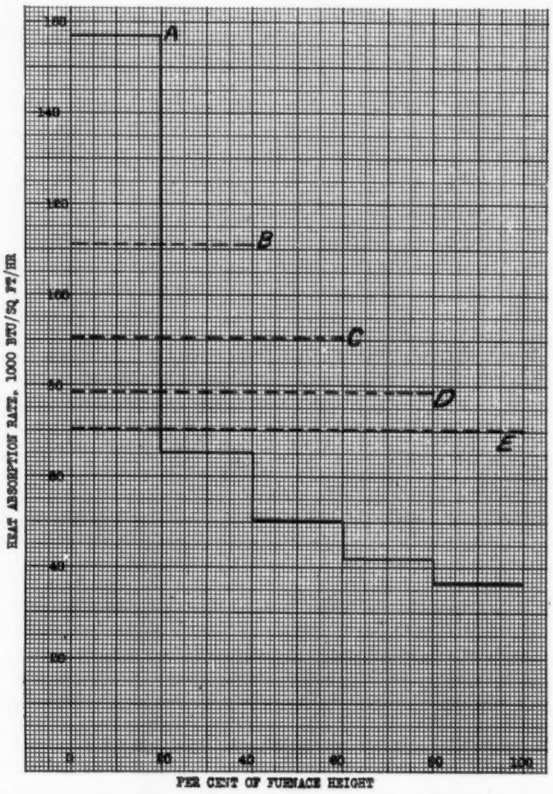


Fig. 5—Probable relationship between heat absorption rate and position of surface in furnace when average absorption rate = 70,000 Btu

Solid lines: Average absorption for various increments
Dash lines: Cumulative averages for various totals

carbon steel for boiler and furnace tubes and the required thickness for various diameters and pressures is plotted in Fig. 6 from the A.S.M.E. Boiler Code, Table P-2, Revised (b).

The conductivity of the metal also appears as a factor in equations (1) and (2). It is dependent on both temperature and composition of the metal. But various published data are not in agreement as to the effect of elevated temperature nor as regards the conductivity at a given temperature. However, since the conductivity is high, the effect of an error will not be great. The correct

value probably lies between 25 and 30 Btu per sq ft per hr per deg F for 1 ft thickness.

If sludge is included in the same category as scale, there are two different factors affecting deposition. Sludge may be defined as undissolved solids in the circulating water of the boiler. It may have come in with the feedwater, chemical treatment, or may result from small particles of scale which have become detached from the tubes. Its deposition is undoubtedly caused by low velocity rather than evaporation and it is not a hard homogeneous solid but may form a compact mechanical mixture of particles of various materials. The phenomenon of scale deposition is different. According to Partridge (c), scale may form even from dissolved solids in the water due to supersaturation at the nucleus of the steam bubble, and a crystal is left on the evaporating surface when the bubble is swept off. This process builds up a homogeneous layer of material firmly bonded to the surface, and there is evidence to prove that the thickness is greatest in the locality of the maximum rate of evaporation. But naturally, as the scale starts to form in this locality, the tube metal temperature is increased and more heat is caused to flow circumferentially to cooler areas on the evaporating surface thus automatically reducing evaporation and rate of scale formation in the scaled area, and increasing evaporation and scale formation in adjacent areas. But in a furnace tube, the rate of heat absorption may be so great that when the furnace side becomes scaled sufficient heat cannot pass to the back or unheated side of the tube to prevent the front or heated side from reaching a dangerous temperature. This, of course, depends on the type of scale being deposited and the rate of deposition or ultimate thickness.

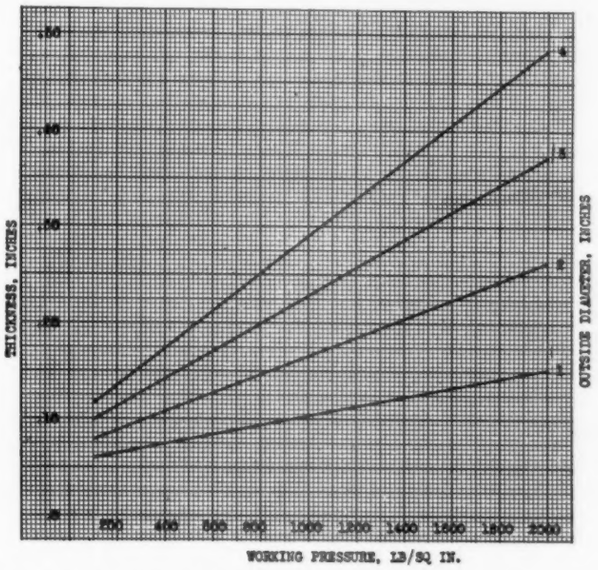


Fig. 6—Minimum tube thickness vs. working pressure for seamless low carbon steel boiler tubes (plotted from A.S.M.E Boiler Code, table P-2, revised)

There are many kinds of scale because there are many kinds of dissolved solids in boiler water. Some of these solids may be present in the feedwater before treatment and some are added in the treatment process. The treatment process aims to eliminate scale-forming compounds and substitute by chemical reaction non-scale-forming compounds; but, unless close control is maintained over the process and frequent checks made by qualified chemists, there is no certainty that the desired results are continuously being obtained. A treatment system that gets out of balance for a week or even a day may deposit enough scale in a furnace tube to raise the hot face temperature to the oxidation point because the rate of heat absorption in furnace tubes is so great.

The temperature drop across the scale deposit and the tube wall are both calculated from equation (2). Therefore, conductivity and thickness affect the temperature drop of scale in the same manner as for the tube, and, although the scale thickness may be minute, the conductivity of some scale materials is also very low so that an almost unbelievable temperature gradient across the scale results.

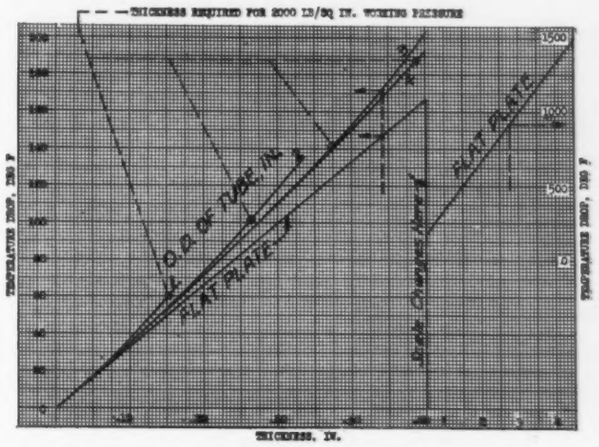


Fig. 7—Temperature drop for various thicknesses of tube and flat plate. Plotted from equations (1) and (2) for Q = 100,000 and k = 25

The conductivity of boiler scale of several types has been reported in the literature by several authors but there is not complete agreement in the values. This may be due to a large extent to variable density or porosity of the deposit although Partridge (c) shows that there is a definite relationship between the chemical composition and density, high silicate scales always having the lowest density and high sulphate scales the greatest. The accompanying Table gives some values of scale conductivity, the source of the data and the name of the investigator. It also includes the conductivity of saturated and superheated steam, the significance of which is discussed below.

It is conceivable that in a boiler or furnace tube containing scale, the scale may become semi-detached from the tube surface in some places due to fluctuating load or shutting down of the unit. It is probable also that in such an instance water will enter the space between the scale and tube and evaporate into steam when the unit is operating. Such a layer of steam will transfer heat only by conduction since the pocket is too small for convection currents. Furthermore, the steam in the pocket may not escape and be replaced by more water, and may therefore become highly superheated. Equation (2) may also be used to calculate the temperature gradient across the steam film.

Another type of steam pocket may form and cause an overheated local area when the conditions are such that

intense radiant heat is applied to the upper surface of a horizontal or nearly horizontal tube in combination with low velocity in the tube. The steam may form a layer of increasing thickness in the direction of flow and the water may flow only along the bottom, or less intensely

THERMAL CONDUCTIVITY OF BOILER SCALE, WATER, AIR, STEEL AND STEAM

Material	Density	Temperature Deg F	Conductivity Btu, Ft/Hr, Sq Ft, Deg F	Observer	Reference
Scale	1.27*	86	0.76	Ernst	Partridge (c)
"	2.14*	86	1.86	"	"
"	0.50*	212–572	0.043–0.060	Eberle & Holzhauer	"
"	1.50*	212–572	0.21 –0.25		"
"	2.50*	212–572	1.01 –1.34		"
"	....	212	1.28–1.98	Eberle & Reutlinger	"
"	....	338	1.75	Croft	"
"	....	365	0.66–2.12	Partridge & White	"
Silicate scale	18.7–62.42†	570	0.05–0.10	Eberle & Holzhauer	Schack (d)
Sulphate scale	125–156†	570	0.34–1.34		
Water	....	162	0.390	E. Schmidt	"
Water vapor	....	570	0.0211	"	"
Air	....	930	0.0304	.....	"
1% C steel	....	570	26.9	.....	"
"	....	1110	21.5	.....	"
Mild C steel	....	600	30	.....	de Baufre (e)
"	....	1100	24.5	.....	"
Low C steel	....	370	25	M.I.T.	B. & W. (f)
"	....	631	26.4	"	"
Saturated steam	....	600	0.117	.....	Steam Tables (g)
Superheated steam	....	1000	0.036–0.109‡	.....	"

NOTES: * Indicates specific gravity.
† Indicates lb per cu ft.
‡ Indicates variable pressure.

heated side of the tube. Even though the steam layer may move along at an appreciable velocity, the lowered heat transfer due to absence of a water film and the low conductivity of the steam layer may result in overheating. The remedy is to use higher velocity or spiral inserts to create turbulence and to force the water in contact with the upper surface.

Temperature Gradient Across the Water Film

The temperature gradient across the water film at the evaporating surface of tubes receiving intense heat from one side, and operating at high pressure, has not, to the writer's knowledge, been measured, but in some furnaces and boilers thermocouple measurements have been made of the hot face temperature of the tubes. Erratic readings may be expected after the couples have been in service a short time but initial readings on different tubes have been consistent. By estimating the absorption rate and first calculating the temperature drop across the tube wall by equation (2), the temperature drop across the film can then be roughly approximated, and, assuming radial flow, the conductance of the film may then be determined from equation (5). It is probable, of course, that this coefficient is considerably affected by pressure, velocity, condition of evaporating surface, concentration of boiler water and other factors but a value of 3000 Btu per sq ft per hr per deg F, or higher, appears reasonable, and a considerable error in U will not greatly affect the conclusions made in this study.

Equation (5) may therefore be used for the calculation of the temperature drop through the film using $U = 3000$.

$$\Delta T = \frac{Q}{U} \times \frac{r_2}{r_1} \qquad (5)$$

where ΔT = temperature drop through water film, deg F
Q = heat absorption rate to outside surface of tube, Btu/sq ft/hr
U = heat transfer coefficient (film conductance) through water film, Btu/sq ft/hr/deg F
r_2 = outside radius of tube
r_1 = inside radius of evaporating surface

The term r_2/r_1 merely corrects the heat absorption rate at the outside surface to the proper value for the inside surface and presupposes radial flow of heat.

Temperature Drop Across Tube Wall and Scale

Having now examined the properties of the most important variables and the manner in which they affect the hot face temperature of the tube, the curves of Figs. 7 and 8 are offered to assist in readily calculating the temperature drop across tube wall and scale for any set of conditions. Equation (2) applies to both cases and since ΔT is directly proportional to Q, it is unnecessary to complicate the curves by introducing variable Q. For convenience, both Figs. 7 and 8 are plotted for a heat absorption rate of 100,000 Btu per sq ft per hr even though, with radial flow, the rate cannot be the same at the scale as at the outside tube surface. Furthermore, since the radiant absorption

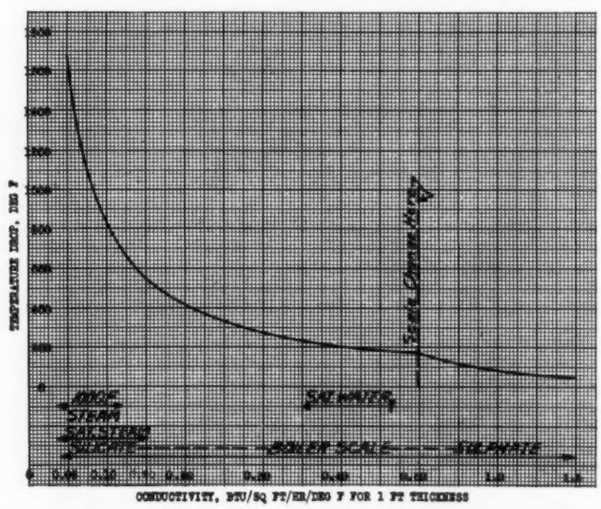


Fig. 8—Temperature drop for 0.01 inch thickness of boiler scale or stagnant steam for various conductivity values based on equation (1) using Q = 100,000

rate is generally expressed in terms of effective projected surface, or area of flame envelope, the average absorption rate at the actual surface of plain closely spaced tubes will be less by the factor $2/\pi$. Therefore, a radiant absorption rate of 150,000 based on projected area would be equivalent to an average of 100,000 at the outside tube surface, but 150,000 again at the inside tube surface (or scale) of a thick boiler tube. It is, however, a simple matter to correct any ΔT reading from Fig. 7 or Fig. 8 in direct proportion to heat absorption for values other than 100,000.

For plotting Fig. 7 the conductivity of steel was taken as 25. The curves illustrate the effect of tube curva-

ture on the temperature drop compared to a flat plate, but the flat plate curve can be used for drums and headers. Used in conjunction with Fig. 6, it will be noted that small diameter tubes will operate at lower metal temperature, other conditions being equal.

Fig. 8 shows the temperature drop across 0.01 in. of boiler scale of various conductivities, but may also be used within the conductivity range for any other film which transfers heat by conduction only. It therefore illustrates that a thin film of steam held in a pocket, even behind scale of high conductivity, or steam trapped in pitted holes, has the same effect as the worst kind of boiler scale and may cause a localized high temperature in the metal sufficient to cause rapid oxidation on the hot face, or even in some cases blistering and failure of the metal.

Summarizing, it will be noted that:

1. Up to the critical pressure, the maximum steam and water temperature inside a boiler tube will only slightly exceed 700 F.

2. The temperature drop across the evaporating film cannot be accurately calculated but will probably not exceed 50 deg F.

3. The temperature drop across the tube wall is greatly affected by the wall thickness which in turn varies for given pressures. By using small diameter tubes for high pressure, the temperature drop across the metal wall may be kept below 100 deg F.

4. For a tube internally free from scale or steam pockets, the maximum metal temperature at the hot face need not exceed 850 F regardless of pressure, or 750 F at 1500 lb per sq in., which is a popular maximum at the present writing. Both of these temperatures are well below the temperature at which rapid oxidation may be expected.

5. A film only 0.01 in. in thickness of certain kinds of boiler scale, or of steam held in a pocket so that it can transfer heat only by conduction, may raise the hot face temperature several hundred degrees, thereby causing rapid oxidation on the face of the tube or sudden failure by blistering and bursting.

6. The treatment and control of boiler water in such a manner as to prevent scale and sludge is of the utmost importance in boiler operation. However, the science of water treatment and control has kept pace with the progress and problems of boiler design to such an extent that it is reasonable for the boiler manufacturer to assume and specify that the internal surfaces will be kept strictly clean by the operating company.

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(b) Table P-2, Revised, Addendum to *A.S.M.E. Boiler Construction Code*, Approved Mar. 1, 1940.

(c) E. V. Partridge, "Formation and Properties of Boiler Scale," University of Michigan, *Engineering Research Bulletin No. 15* (1930).

(d) Alfred Schack, "Industrial Heat Transfer," John Wiley and Sons, Inc. (1933).

(e) W. L. de Baufre, "Stresses in Boiler Tubes Subjected to High Rates of Heat Absorption," *A.S.M.E. Transactions FSP*, Vol. 55, No. 6 (1933).

(f) Babcock & Wilcox Tube Co. *Technical Bulletin 6A* (1935).

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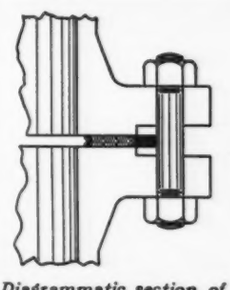
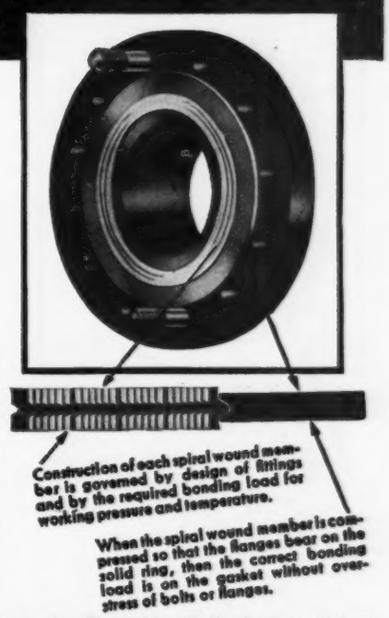


Diagrammatic section of a C-G Gasket with typical Raised Face fittings showing the flanges compressed to the thickness of the solid metal member.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pH by Simple Titration

By WILLIAM MADDOCK*

MORE and more the importance of the pH value is being recognized for the control of process and in the waters used for power and industrial purposes. Some of the processes need a rigid and close control and the results justify the expense in connection with the securing of accurate pH readings. However, there are many places where such accuracy is not required.

Indicators for pH, of either the electric or the color comparison types, are relatively expensive and a fairly well-trained operator is needed to handle the equipment. Even in cases where the water samples are sent out for check, the pH determinations frequently are omitted. What has been needed is a simple, rapid, cheap method of determination that any one can use.

In the October 1931 issue of COMBUSTION, C. E. Joos got off to a good start when he presented a formula and chart showing the correlation of free CO_2 to pH using the common indicators of methyl orange and phenolphthalein. This chart was revamped by the writer in order that it could be extended. To make the chart symmetrical and continuous the same indicators were used, but Mr. Joos's lines near the zero CO_2 line could not be checked.

To make the extension, several hundred alkalinity and pH determinations were made and plotted. No attempt was made to reduce the results to a mathematical expression, and no unimpeachable proof of the findings was offered. Those tests made personally were conducted on a Hellige comparator but more than one hundred were made on samples sent to commercial laboratories. Up to the line pH equals 10.0, all of the points fell close to the lines as shown. Beyond that there was a tendency for the points to scatter. Checks made on samples from Albuquerque, N. M., and from results at the Utility Management Corporation reveal that when the phosphate concentration is over 20 ppm the value of $2P$ minus B† should be substituted for the M.O. alkalinity. The $2P$ minus B is the result from either the Hall or Allis-Chalmers method of boiler-water analysis. All of the results shown are ppm in terms of calcium carbonate.

Through the limited range that the writer has had the opportunity to check the chart, it was found to give good and useful approximations to the pH value. It should be pointed out that the pH value is found simultaneously with the regular alkalinity titrations that are probably being run in any event. If for nothing else, it has been found useful in selecting the proper indicator for a color comparator.

This chart is presented for what it is, namely, an approximation to pH by simple titration.

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* The Tucson Gas, Electric Light and Power Company, Tucson, Ariz.

† The methyl orange (M.O.) reading indicates total alkalinity. The P or phenolphthalein reading gives the hydroxide alkalinity plus $^1/_2$ the carbonate alkalinity. The B reading indicates hydroxide alkalinity alone. $2P$ minus B therefore equals M.O., or total alkalinity.

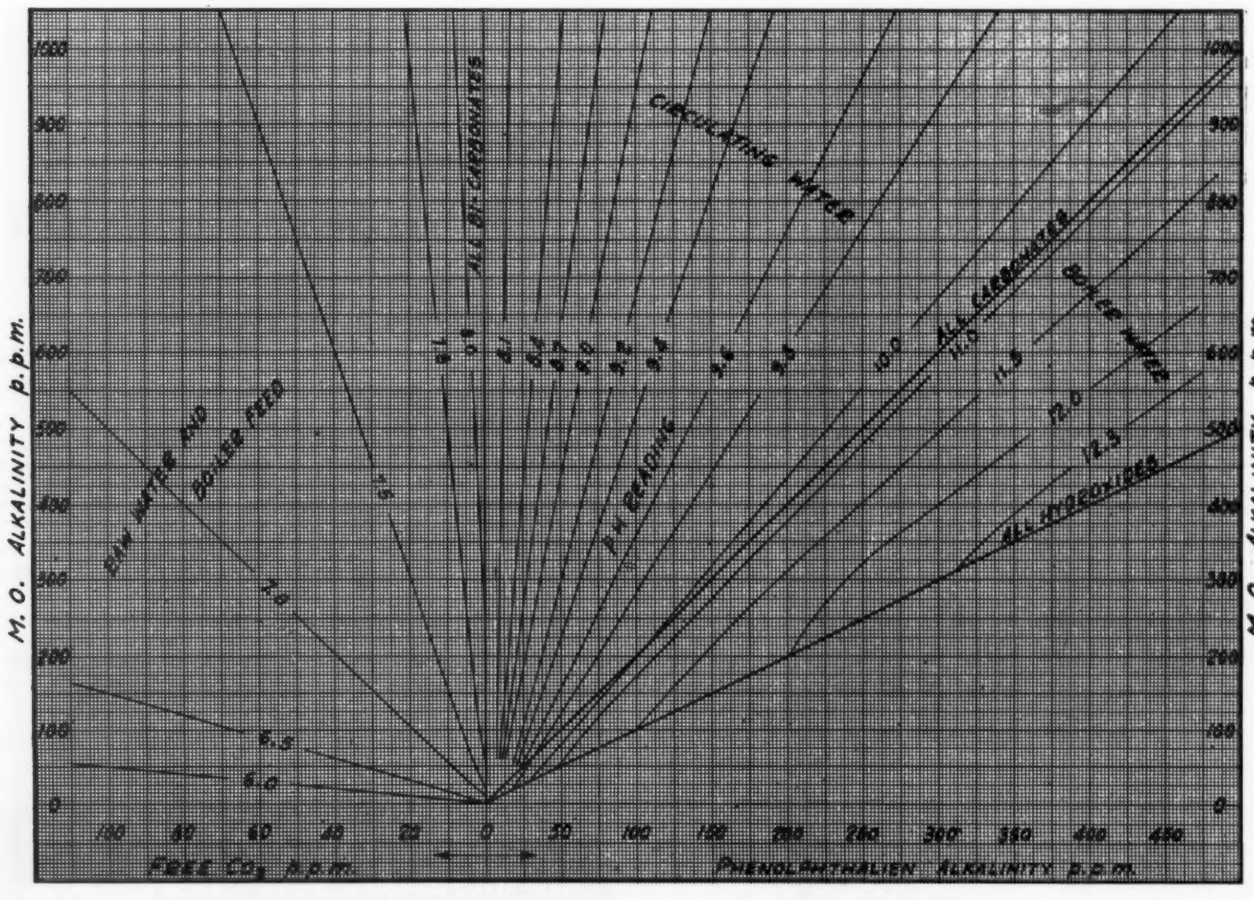


Chart showing the correlation of free CO_2 to pH

Bituminous Coal Prices Announced

THE Bituminous Coal Division of the Department of the Interior has completed work on the long-awaited minimum coal prices which will become effective on September 3. These prices range from a low of ten cents a ton at the mine, for a low-grade of coal dust produced in Indiana, up to a high of $5.25 a ton at the mine for a high grade of lump coal produced in the state of Washington. The prices cover substantially all of the commercial bituminous coal produced, including the small-size slack coals, generally used to generate power and heat for industry, as well as the lump and prepared sizes for domestic use. They also reflect the differences in quality of the different coals and other factors, as required by law.

The prescribed minimum prices are those below which Code member producers may not sell their coal, at the mines, without incurring a penalty involving a 19½ per cent tax and the possibility of suit for triple damages by injured Code member competitors. However, producers may charge more than the minimum prices when conditions permit them to do so. On the other hand, producers who are not Code members may sell their coal at any price, subject to a 19½ per cent tax; but such cases will be few as the producers of substantially all the commercial bituminous coals mined in the United States have become Code members.

Obviously, the price schedules are too extensive to be quoted here in full, and are available upon application to the Coal Division at Washington, D. C. However, those applying to a few of the more important industrial localities will be given.

Some Examples of Typical Minimum Prices

Following are examples of the minimum prices per ton, f.o.b. mine, for coals produced in District 1 (Central Pennsylvania, the state of Maryland, and Mineral, Grant and Tucker counties in West Virginia) shipped by rail or tidewater boats to Portland, Me., Boston, Providence, New Haven, Lawrence and Worcester, Mass., Buffalo, Rochester, Albany, Troy, New York City, Philadelphia, Baltimore and all other points except Washington, D. C., and except ports to which coal is shipped via boat on the Great Lakes:

	Best Grade	Poorest Grade
*Slack (¾-in. × 0)	$2.15	$1.80
*Nut-slack (2-in. × 0)	2.35	1.90
Run-of-mine (nut, pea)	2.45	2.10
All lump and double-screened coal over two inches in size	2.70	2.35

(* The minimum prices, f. o. b. mine, for ¾-in. × 0 slack for rail shipment to Market Area 9 (Wheeling) and Area 11 (Youngstown), $2.35 per ton for the best grade and $2 per ton for the poorest grade. Those for the 2-in. × 0 nut-slack for shipment to the same market areas are $2.45 per ton for the best grade and $2 per ton for the poorest grade. Minimum prices for the other sizes are the same as for other cities listed above.)

Minimum prices per ton, f.o.b. the mine, for typical coals produced in Western Pennsylvania (District 2) and Northern West Virginia (District 3) and shipped by rail or tidewater boats to points in New England, the eastern half of the states of New York, Pennsylvania and Maryland, and the cities of New York, Philadelphia, Baltimore, Troy, Syracuse, Albany, etc., are:

	6-in. Lump	Nut-Pea	Mine Run	1¼-in. × 0 Slack	¾-in. Slack	⅜-in. Slack
District 2 (Western Pennsylvania) Coals						
Best grade	$2.48	$2.13	$2.13	$1.98	$1.88	$1.78
Poorest grade	1.98	1.73	1.73	1.63	1.53	1.58
District 3 (Northern West Virginia) Coals						
(Best grade Pittsburgh low sulphur seam)	$2.33	$2.03	$2.03	$1.88	$1.78	$1.78
Poorest grade (other seams)	2.08	1.78	1.78	1.63	1.53	1.53

Prices, f.o.b. the mines, for typical coals produced in Western Pennsylvania (District 2), Northern West Virginia (District 3), West Virginia "Panhandle" (District 6) and Ohio (District 4) and shipped, by rail, to Buffalo and Rochester and other points in Market Area 4, which comprises roughly Western New York are:

	6-in. Lump	Nut-Pea	Mine Run	1¼-in. × 0 Slack	¾-in. × 0 Slack	⅜-in. × 0 Slack
Western Pennsylvania (District 2) Coals						
Best grade	$2.65	$2.20	$2.20	$2.05	$1.95	$1.85
Poorest grade	2.10	1.80	1.80	1.65	1.55	1.65
District 3 (Northern West Virginia) Coals						
(Best grade Pittsburgh low sulphur seam)	$2.35	$1.95	$1.95	$1.80	$1.70	$1.70
Poorest grade (other seams)	2.10	1.70	1.70	1.55	1.45	1.45
West Virginia Panhandle (District 6) Pittsburgh No. 8 Seam Coals						
	$2.25	$1.85	$1.85	$1.70	$1.60	$1.60
Ohio (District 4) No. 8 Seam Coals						
	$2.25	$1.85	$1.85	$1.70	$1.60	$1.60

Minimum prices, f.o.b. the mines, for typical coals produced in Western Pennsylvania (District 2), Northern West Virginia (District 3), West Virginia "Panhandle" (District 6) and Ohio (District 4) and shipped, by rail, to Erie, Pa., and other points in Market Area 10, which comprises the Northwestern tip of Pennsylvania are:

	6-in. Lump	Nut-Pea	Mine Run	1¼-in. × 0 Slack	¾-in. × 0 Slack	⅜-in. × 0 Slack
Western Pennsylvania (District 2)Coals						
Best grade	$2.49	$2.04	$2.04	$1.89	$1.79	$1.69
Poorest grade	1.94	1.64	1.64	1.49	1.39	1.49
District 3 (Northern West Virginia) Coals						
(Best grade Pittsburgh low sulphur seam)	$2.19	$1.79	$1.79	$1.64	$1.54	$1.54
Poorest grade (other seams)	1.94	1.54	1.54	1.39	1.29	1.29
West Virginia "Panhandle" (District 6) Pittsburgh No. 8 Seam Coals						
	$2.09	$1.69	$1.69	$1.54	$1.44	$1.44
Ohio (District 4) No. 8 Seam Coals						
	$2.09	$1.69	$1.69	$1.54	$1.44	$1.44

The following prices apply to typical coals produced in Western Pennsylvania (District 2), Northern West Virginia (District 3), West Virginia "Panhandle" (District 6) and Ohio (District 4) and shipped, by rail, to Youngstown and other points in Market Area 11 which includes the nearby territory:

	6-in. Lump	Nut-Pea	Mine Run	1¼-in. × 0 Slack	¾-in. × 0 Slack	⅜-in. × 0 Slack
Western Pennsylvania (District 2) Pittsburgh Seam Coals						
Best grade	$2.75	$2.30	$2.30	$2.05	$1.95	$1.85
Poorest grade	2.20	1.80	1.80	1.55	1.45	1.65
District 3 (Northern West Virginia) Coals						
(Best grade Pittsburgh low sulphur seam)	$2.36	$1.96	$1.96	$1.71	$1.61	$1.61
Poorest grade (other seams)	2.06	1.61	1.61	1.41	1.31	1.31
West Virginia "Panhandle" (District 6) Pittsburgh Seam Coals	$2.30	$1.85	$1.85	$1.65	$1.55	$1.55
Ohio (District 4) No. 8 Seam Coals	$2.30	$1.85	$1.85	$1.65	$1.55	$1.55

Examples of minimum prices, for typical Pittsburgh seam coals produced in District 2 (Western Pennsylvania) for shipment from Lake Erie loading ports to all ports on the Great Lakes receiving such shipments, including Toronto, Detroit, Milwaukee, Duluth, etc., are:

	6-in. Lump	Nut-Pea	Run of Mine	1¼-in. × 0 Slack	¾-in. × 0 Slack	⅜-in. × 0 Slack
Best grade	$2.30	$2.15	$2.15	$2.00	$1.90	$1.80
Poorest grade	1.80	1.75	1.75	1.55	1.45	1.60

Those for Pittsburgh seam coals, produced in District 2, for shipment from Lake Ontario ports, to all ports on the Great Lakes receiving such shipments are:

	6-in. Lump	Nut-Pea	Mine Run	1¼-in. × 0 Slack	¾-in. × 0 Slack	⅜-in. × 0 Slack
Best grade	$2.18	$2.03	$2.03	$1.88	$1.78	$1.68
Poorest grade	1.68	1.63	1.63	1.43	1.33	1.48

Prices, f.o.b. the mine, for typical Northern West Virginia (District 3) low-sulphur Pittsburgh seam and other seam coals for shipment via Great Lakes boats from Lake Erie loading ports to all ports which receive such shipments, including Detroit, Duluth, Toronto, Milwaukee, etc., are:

	6-in. Lump	Nut-Pea	Mine Run	1¼-in. × 0 Slack	¾-in. × 0 Slack	⅜-in. × 0 Slack
(Best grade Pittsburgh low sulphur seam)	$1.95	$1.85	$1.85	$1.70	$1.60	$1.60
Poorest grade (other seams)	1.70	1.60	1.60	1.40	1.30	1.30

The following minimum prices apply to Illinois (District 10) coals shipped by railroad for sale in Chicago, Springfield, Quincy, Rockford, Decatur, Rock Island, Moline, Davenport, Clinton, Milwaukee, Madison, Minneapolis and St. Paul and for all Market Areas in which Illinois coals are sold excepting Areas 40, 70, 71, 72 and 74 (which are in Missouri and a small portion of Illinois adjacent to St. Louis):

Southern Illinois (Franklin County) lump (6-in.), $2.65 per ton
Southern Illinois (Franklin County) raw slack (1½-in. × 0), $1.60 per ton
Southern Illinois (Franklin County) washed slack (1½-in. × 0), $1.80 per ton
Central Illinois lump (6-in.), $2.05 per ton
Central Illinois raw slack (1½-in. × 0), $1.15 per ton
Central Illinois washed slack (1½-in. × 0), $1.45 per ton
Bellville "Better Grade" lump (6-in.), $1.90 per ton
Bellville "Better Grade" raw slack (1½-in. × 0), 95 c. per ton
Bellville "Better Grade" washed slack (1½-in. × 0), $1.30 per ton
Bellville "Standard Grade" lump (6-in.), $1.75 per ton
Bellville "Standard Grade" raw slack (1½-in. × 0), 95 c. per ton
Bellville "Standard Grade" washed slack (1½-in. × 0), $1.25 per ton
Fulton-Peoria lump (6-in.), $2.05 per ton
Fulton-Peoria raw slack (1½-in. × 0), $1.15 per ton
Fulton-Peoria washed slack (1½-in. × 0), $1.50 per ton

It should be emphasized that the foregoing prices are minimum "f.o.b. at the mines" and that freight, handling and other charges must be added to arrive at the delivered price to the consumer.

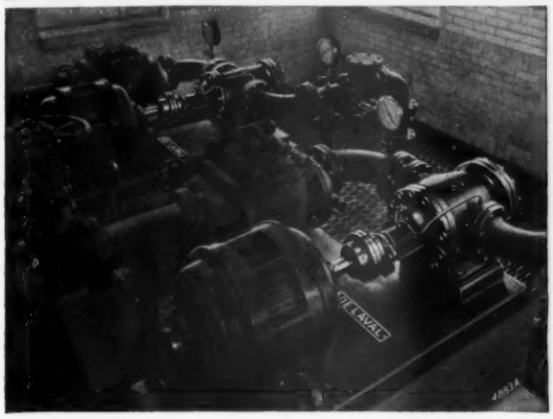
Port Washington Station to be Extended

The Port Washington Station of the Wisconsin Electric Company, which has long held the world's record for efficiency, is to be increased in capacity by the addition of a second 80,000-kw turbine-generator operating at a throttle pressure of 1230 lb and 850 F total steam temperature. Steam will be supplied by a 690,000-lb per hr three-drum C-E boiler vertically fired with pulverized coal from the existing storage system the capacity of which will be increased by the addition of two more roller mills. An extension of the present building will be necessary to house the new turbine and boiler.

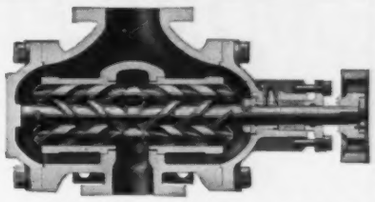
VULCAN SOOT BLOWERS

. . . are readily meeting high temperature conditions without makeshift in design, material or parts. The sound and proven principles of the Vulcan valve operating head, bearings and elements guarantee operating economies which make both the annoyance and cost of frequent servicing unnecessary.

VULCAN
SOOT BLOWER CORPORATION
DUBOIS, PENNSYLVANIA



IMO for fuel oil



These De Laval-IMO pumps transfer 100 g. p. m. each of Bunker C against 100 lbs. pressure. Other IMO's in the same plant deliver the oil to the burners at 300 lbs. All are coupled directly to the driving motors. There are no gears, and no valves, and the delivery is uniform, as from a continuously moving piston. Ask for Catalog I-62.

IMO I MOVE OIL

DE LAVAL STEAM TURBINE CO., TRENTON, N. J.

Maximum Oil Recovery Assured by Present Methods

More than 99½ per cent of the recoverable oil known today in underground reservoirs ultimately will be produced by a continuance of present production methods, according to a statement issued by the American Petroleum Institute.

Underground waste of oil virtually has been eliminated in the development of America's oil reserves by the continual discovery of more efficient oil-production methods, by the tremendous advances in the knowledge of the occurrence and behavior of oil, gas and water in formations as deep as three miles underground, and by the application of adequate conservation laws and restricted rates of oil production in most of the leading oil states.

Within recent years the development of new tools and instruments for taking samples and measurements of the actual oil formation thousands of feet underground has thrown new light on how oil occurs in the formation. As a result the estimation of the amount of oil actually present in a given field substantially has been changed. Now petroleum engineers believe that even in the past, under unrestricted production, underground waste of oil was not nearly as great as was supposed, and that today this avoidable waste has been reduced to less than one-half of one per cent of the ultimate reserve.

Manual of Ordinances and Requirements

This is the official publication of the Smoke Prevention Association of America, Inc., which is prepared in the interest of fuel combustion and the elimination of smoke and air pollution. It consists of papers presented in May before the 34th Annual Convention of the Association together with articles describing flue-dust samples, methods of reducing fly ash, model smoke abatement ordinance methods of measuring air pollution and a questionnaire on smoke prevention which is a summary compilation of the answers to a group of questions concerning population, area, amount and type of fuel burned, persons and departments in charge of smoke abatement, methods of determining smoke density, density prohibited, penalties and the like for the principal cities of the United States. The papers covered such timely subjects as: atmospheric corrosion, smoke index, the law as applied to air pollution, mechanical firing of solid fuel, locomotive smoke abatement, methods of firing low- and high-volatile coals and the like.

There are 160 pages in the 1940 Manual which sells for sixty cents, a slight advance over previous annual editions, in view of the somewhat greater amount of information and data included. This compilation is prepared with a view to meeting a demand from municipalities, architects, engineers and manufacturers of fuel-burning equipment concerned with smoke abatement.

BECO-TURNER

Every Beco-Turner Baffle is a "tailor-made" installation, designed to meet the individual requirements of the boiler and fuel-burning equipment. Let us design a Beco-Turner Baffle which will improve the operation of your boiler. Adaptable to all types of water tube boilers—horizontal, bent-tube, low-head, etc. Write for catalog giving detailed information.

PLIBRICO JOINTLESS FIREBRICK CO.
1855 KINGSBURY ST., CHICAGO, ILL.

GAS-TIGHT!

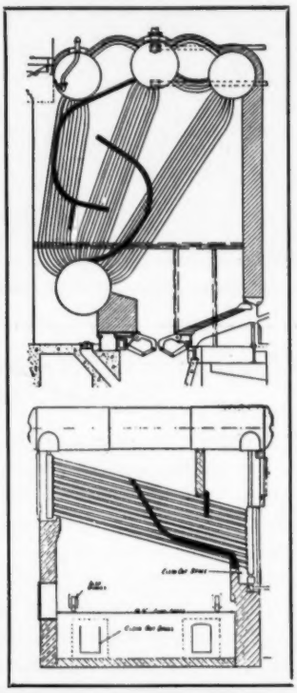
Beco-Turner Baffles are constructed of self-hardening refractory material. They are gas tight when originally installed since the tubes are snugly mortared into the baffle wall. They remain gas tight because the patented expansion joints shown opposite prevent cracks and leaks. Illustration also shows interlocking tube blocks which form footing for baffle.

BAFFLES

MORE POWER . . .
BETTER BOILER OPERATION .

with

Enco Streamline Baffles



because:

. . . they are *designed* to insure better heat distribution, lower flue gas temperatures and higher efficiencies, and the design is based on *results already achieved.*

. . . they are *flexible.* By streamline and curved construction, it is possible to meet various tube and superheater arrangements and obtain maximum rate of heat transfer.

. . . surfaces are *smoothly curved.* Enco Streamline Baffles, by eliminating angle joints, eliminate dead gas pockets and eddy currents. By so doing they decrease draft loss and make it easier for soot blowers to do their work more effectively.

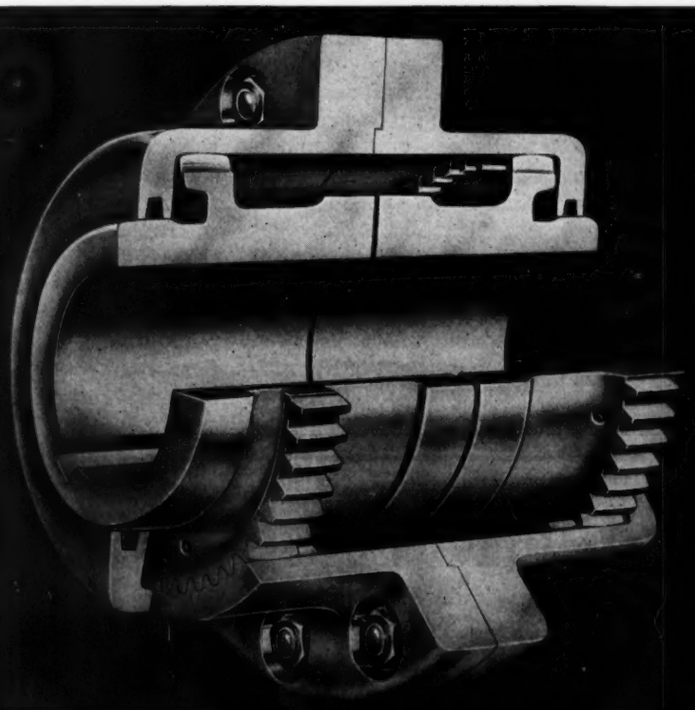
. . . they are *gas tight.* Construction work is done by experienced mechanics who are specialists in building baffle walls exactly to Enco specifications. Provision is made in both design and construction for removal of tubes with the least possible disturbance of baffle walls.

. . . *Enco materials are carefully selected.* Only the finest obtainable refractories are used for Enco tile and plastics. Special processing is employed to insure resistance to high temperatures and maximum life in service.

Ask for Bulletin BW-40
containing valuable information
Detailed engineering data on modern baffle wall practice for all types of water tube boilers—FREE on request.

THE ENGINEER COMPANY 75 West Street, New York, N. Y.

POOLE



A COPY OF CATALOG GIVING FULL DESCRIPTION AND ENGINEERING DATA SENT UPON REQUEST.

FLEXIBLE COUPLINGS

POOLE FOUNDRY & MACHINE COMPANY WOODBERRY, BALTIMORE, MD.

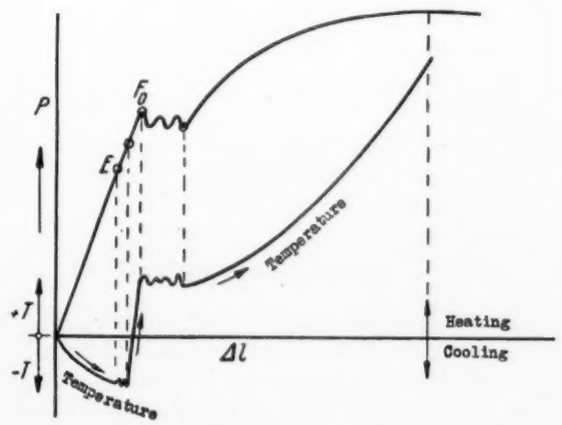
STEAM ENGINEERING ABROAD

As reported in the foreign technical press

The Entropy Diagram for Structural Materials

In a recent article by Dipl.-Ing. W. Büttner VDI, Berlin, which is reviewed in *Archiv für Wärmewirtschaft und Dampfkesselwesen* for March 3, it is shown that by means of an entropy diagram for structural materials it may be possible to replace the usual safety factor, used in designs, by rules based on physical properties of the materials.

Consider for example only tension. It has been known that a material placed under tension becomes warm. If, however, the temperature changes of a test piece are



Temperature curve and stress-strain diagram of a tension test piece

P = stress, Δl = elongation or strain, E = elastic limit, F_0 = yield point

observed, it will be found that at first there is a cooling as shown in the diagram here reproduced. The author has found this same characteristic in numerous tests made on a variety of materials. The temperature reverses from cooling to heating only after having passed the elastic limit.

In the theory of gases one speaks of "ideal gases" which may expand adiabatically. Similarly one may conceive an "ideal body" for solids which may expand adiabatically. Actual gases, however, expand polytropically under given conditions and so the expansion of actual solid bodies, such as test pieces, is polytropic. A great number of measurements made on the usual round and flat test pieces of various kinds of irons and steels and on brass and copper, showed a polytropic temperature drop to a limit which lies above the elastic limit, and in many cases approached the range of the yield point.

The author shows characteristic curves for steel and copper which disclose that the materials may only be used within the cooling range. Within this range, loading and unloading may be approximately considered as a reversible process. The material represents a work accumulator in which the work accumulated during elongation may be expressed as a heat quantity and the heat loss during the temperature drop appears again as potential work in the strain of the material.

Since structural materials are not perfect elastic bodies, the entire cooling range cannot be utilized. The incomplete elasticity may be clearly recognized in the return of the temperature when the stress is released. The return to temperature does not exactly retrace the cooling curve but follows what the authors term a temperature hysteresis, analogous to the stress hysteresis.

The author then discusses the theoretical aspects of the polytropic temperature changes, the work-entropy diagram and discloses the safety factor in the latter.

Fineness of Grinding and Efficiency with Different Type Mills

An article in the May 1940 issue of *Archiv für Wärmewirtschaft und Dampfkesselwesen* gives the results of comparative tests between a ball-race pulverizer and a paddle-type mill such as is used extensively in Germany.

In the Ruhr district a sectional-header boiler unit was equipped with a mill of the ball-race type, arranged for direct firing. The influence of fineness of grinding upon the overall efficiency was determined. Later the mill and separator were replaced by an arrangement in which a shaft served as separator and in which the construction and characteristics were those of the so-called furnace chamber mill (Kramer mill). Another series of tests were then conducted on the reconstructed unit.

Three tests were made on each installation for high, intermediate and low loads and the principal results are tabulated in the article.

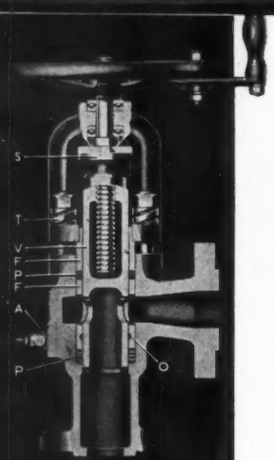
The efficiency of the boiler was fairly independent of load and was, for the high capacity mill about 80 per cent and for the furnace chamber mill about 74 to 75 per cent. Since the losses due to sensible heat of the flue gas, as well as the losses due to radiation, etc., were substantially the same in both cases, the drop in efficiency for the furnace chamber mill was entirely due to the unconsumed carbon loss, since the fuel did not have time to burn because of its coarseness. The unconsumed carbon loss amounted to 3.5 per cent for fine grinding and to 9.5 per cent for coarse grinding.

The sieve analyses of the two types of grinding are given in charts in the article, as are also the shaft power consumptions for the mills.

The high capacity mill had a power consumption when idling of 17.2 kw and the sump mill 29.2 kw. The added power for fine grinding was 7.13 kwhr per ton and for coarse grinding 4.64 kwhr per ton. The power consumption for the main fan is somewhat higher in the case of the ball mill, about 4 kw (10 per cent of the

YARWAY EQUIPPED . .

A Mark of Good Engineering

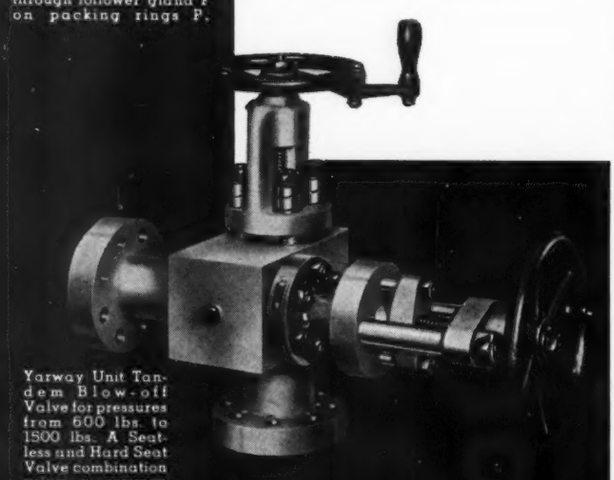


Yarway Seatless Blow-off Valve. Operation: After Valve is closed, shoulder S on plunger V contacts with upper follower gland F, forcing it down into body and compressing packing P above and below port. Annular groove O connects with Alemite fitting A for lubricating plunger and packing. Yoke springs T maintain continuous pressure through follower gland F on packing rings P.

Yarway Blow-off Valves are used singly or in tandem in more than 12,000 plants in 67 different industries . . . Regarded as a standard of quality by leading steam plant designers and builders of steam generating equipment . . . Selected for Federal, State and Municipal Institutions . . . Built for all pressures up to 2,500 lb. . . . Write for Catalog — Section B-420, up to 400 lb. pressure; Section B-430 for higher pressures.

YARNALL-WARING COMPANY

101 Mermaid Avenue, Phila.



Yarway Unit Tandem Blow-off Valve for pressures from 600 lbs. to 1500 lbs. A Seatless and Hard Seat Valve combination using a common forged steel body.

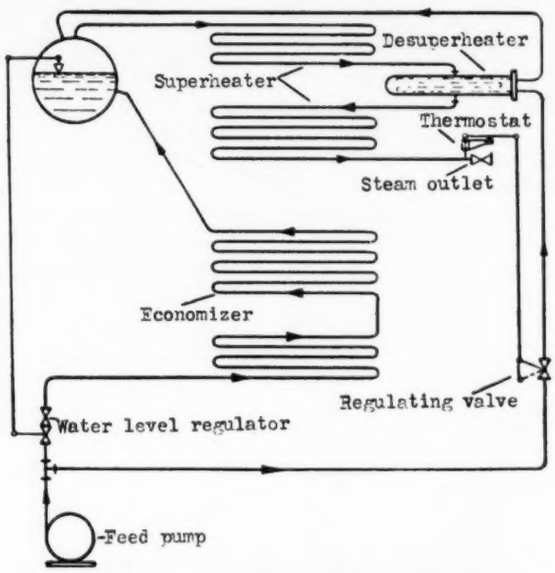
YARWAY

BLOW-OFF VALVES

necessary mill power). The finer grinding was therefore accomplished with but a small increase in power and yielded a substantially higher overall efficiency of the unit.

Superheated Steam Cooler

Cooling superheated steam may be accomplished by injection of condensate or by means of a surface cooler. When injecting water, there is danger of depositing the impurities of the condensate within the superheater tubes or later on the turbine blades. Surface coolers



Arrangement for desuperheating steam

generally use either boiler water or feedwater for cooling the steam and regulation has been attained by a three-way valve which sends more or less steam through the cooler. This involves large and costly steam lines and fittings.

A new superheated steam cooling arrangement described in *Archiv für Wärmewirtschaft und Dampfkesselwesen* of May 1940 is shown in the accompanying sketch. A portion of the feedwater is bypassed and introduced in variable quantity into a tube bundle within a drum located intermediate of two superheater sections through which the steam flows. The feedwater is evaporated within the tube bundle and is more or less superheated and then led to the steam drum of the boiler. In this way the same effect of injecting water is obtained in that the heat is carried away but contamination of the steam is impossible.

British Engineers and the War

Engineering (London) of July 19 reports steps that are being taken by the electricity supply industry in England to conserve strategic materials and to control the employment of technicians and skilled workers for the fullest prosecution of the war without curtailment of essential service.

In order to conserve steel the Electricity Commissioners have authorized dispensing with steel armoring on metal-sheathed underground cables ordered for use in generating stations, and have modified the earlier

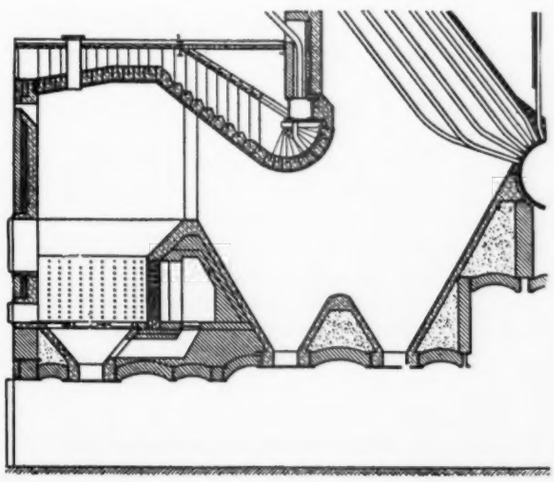
regulations of 1937 pertaining to the manufacture of paper insulated cables.

As regards personnel, there has been an exodus to munitions factories such as to incur difficulties in the efficient operation of the power companies. Hence it has become necessary to invoke the "1940 Restriction on Engagement Order" by which employment exchanges, as set up for the emergency, will be prevented from transferring key employees from power companies to other employment.

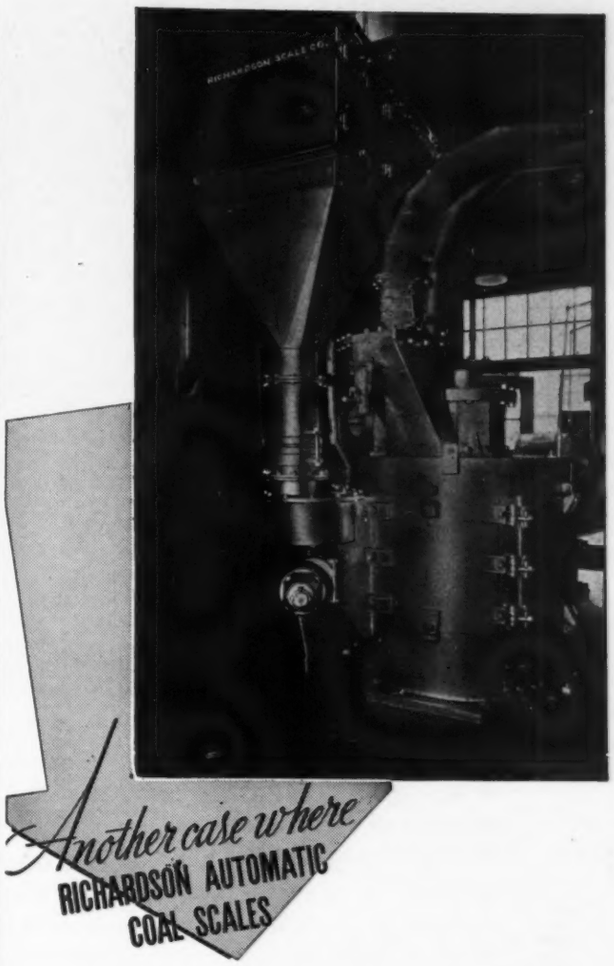
Shortly before the outbreak of the war the British Ministry of Labor, with the assistance of the engineering societies, undertook the compilation and classification of all persons possessing specialized technical qualifications, from which to supply the needs of the government and of industry engaged in war work. This resulted in the classification of about 22,000 engineers of which it is estimated that only about 800 are not now employed. It is assumed that of those employed a large proportion is already engaged in war work, and the number available for such work, either in non-essential industries or unemployed is not great; yet the government has recently issued a preemptory order requiring all persons normally engaged in certain branches of engineering to register, under heavy penalties for non-compliance.

Refuse-Burning Furnace

An article by Dr.-Ing. A. Zinzin in *Zeitschrift des Vereines deutscher Ingenieure* of March 23 describes a design of furnace that has been found satisfactory for burning bagasse and similar fuels such as bark, grain, husks, etc. As shown in the sketch, this furnace is of the pot type, the refractory-lined pot being in the shape of a horseshoe and having a series of holes through the wall for the admission of air. The grate is flat and ash is discharged through the cone-shaped hopper beneath the grate. A rather large combustion chamber is provided and the shape of the arch is such as to direct the gases downward over the dust hoppers, with a sharp reversal of flow before entering the first boiler pass. Thus a minimum of dust and cinders is deposited on the boiler heating surfaces.



Section through pot-type furnace for burning bagasse and other waste fuels



CUT STEAM COSTS 33-1/3%
PER 1,000 LBS.

In thousands of boiler rooms like this, Richardson Coal Scales have put operations under full control, cut costs and saved money.

Figured on a straight dollar and cents basis Richardson Automatic Coal Scales in your boiler room will return their cost many times over by avoiding coal waste alone.

Because Richardson Automatic Coal Scales do their work automatically and continuously and record weight on a reliable mechanical counter you will know at a glance what each boiler is producing, and will know what to do to save coal by avoiding waste. There is a size and type suited to your particular boiler room layout. Write today for Booklet No. C-6239, and learn how to get better boiler room performance and low power costs.

RICHARDSON

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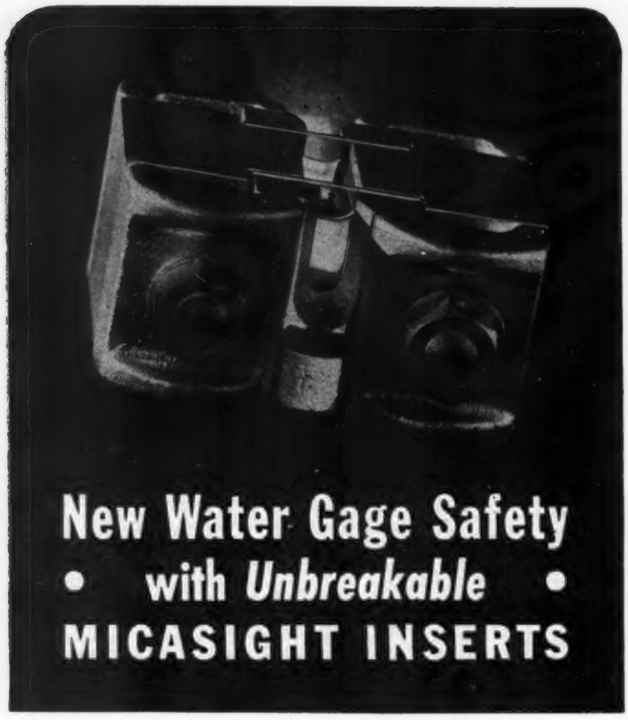
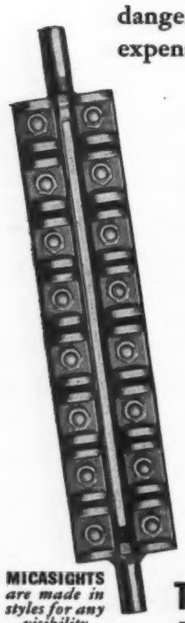
RICHARDSON SCALE COMPANY, CLIFTON, N. J.



YOUR high pressure boilers need this pressure-defying MICASIGHT to make safe the important job of watching water levels. You're money ahead when you remove danger of flying glass — save the bother and expense of constantly renewing gage glasses.



Mica *bends,* but doesn't shatter. Even the thin sheets you see above resist the highest pressure you'll use. The Reliance forged steel body clamps mica securely, leak proof. Easily replaced if dirty after long use. Can be illuminated for bright sharp reading high on the drum.

Micasight Inserts install quickly in your present gage valves or in long-lasting Reliance Forged Steel Valves. Install this praise-winning safety gage as hundreds of progressive engineers have done. . . Write today for MICASIGHT Bulletin.

MICASIGHTS *are made in styles for any visibility measurement*

The Reliance Gauge Column Co.
5902 Carnegie Avenue • Cleveland, Ohio

Reliance
Boiler Safety Devices since 1884

Accident Rates in the Public Utility Industries in 1939

Throughout the public utility industries in 1939 there was maintained an average accident frequency rate[1] of 11.55 and severity rate[2] of 1.57. This frequency rate was 2 per cent below the 11.83 average for all industries but 3 per cent higher than in 1938. The severity rate was 11 per cent higher than the 1.42 general average but 20 per cent lower than the 1938 average. The reduction in severity over 1938 was twice as great as that for all industries but the increase in frequency compared unfavorably with the general reduction of 5 per cent by industry, as reported by the National Safety Council.

The large utilities bettered the records of the whole utility field by attaining a frequency of 10.54 and a severity of 1.43. Small companies throughout industry as a whole reduced frequency 4 per cent and severity 18 per cent, making the best result in comparison with 1938. Only gas and electric and straight electric companies made reductions in both injury rates from 1938 to 1939 in the utility field. The outstanding accomplishment of public utilities was a reduction of 71 per cent in frequency of fatalities. A new all-time no-injury record of 4,377,640 man-hours was established by the Fall River Electric Light Company. The record began June 18, 1930, and continued unbroken on January 9, 1940.

Injury rates for 1939 were based on the records of 623 companies whose employees worked 768,741,000 man-hours during the year.

[1] Injury frequency rate is the number of reportable injuries per million man-hours of exposure.
[2] Injury severity rate is the number of days lost as the result of reportable injuries, per 1000 man-hours of exposure. This rate includes arbitrary charges for permanent disabilities and deaths, in accordance with the standard scale.

Business Notes

The C. O. Bartlett & Snow Company, Cleveland, O., materials handling and conveying machinery manufacturer, has appointed **C. O. Bartlett,** son of the founder of the company, as district manager in the Detroit territory.

National Aluminate Corporation, Chicago, has appointed **J. T. Nicholson** as junior engineer for the southeastern states with headquarters at Winston-Salem, N. C., under the direction of W. O. Widener.

Combustion Engineering Company, Inc., New York, announces the appointment of **Albert R. Chase** as district manager of its Pittsburgh district office. Mr. Chase was for several years identified with sales and field service in the company's Philadelphia district. **Roy L. Ehmann** has been placed in charge in the Pittsburgh, Cleveland and Cincinnati territories of the separate sales of Elesco superheaters and economizers. His headquarters are in the First National Bank Bldg., Pittsburgh. **Charles Keene, Jr.,** has been transferred from the Estimating Department in New York to contract sales in the Philadelphia district and **A. O. Soderberg** has joined the company's contract sales staff in that district.

Western Precipitation Corporation, Los Angeles, has opened a sales and engineering office in the Marquette Bldg., Chicago, with **A. W. Robinson** in charge of operations in the central states.

NEW CATALOGS AND BULLETINS

Any of these publications will be sent on request.

Blowers and Compressors

A new 52-page catalog on centrifugal blowers and compressors has been issued by De Laval Steam Turbine Company. Chapters are included on (1) the construction of centrifugal blowers and compressors and their characteristics, (2) turbine and motor drives, (3) governing, (4) properties of gases and laws of compression, (5) selecting a compressor for given conditions and calculating horsepower and (6) calculating pressure drop in piping. There are numerous reproductions of excellent wash drawings showing internal details and exterior views, as well as curves and tables.

Boiler Feedwater Regulators

Bulletin 429 describing the Copes Flowmatic Regulator, a simplified two-element steam-flow type, has been released by Northern Equipment Company. Printed in three colors, this 16-page, $8^1/_2 \times 11$-in. bulletin is illustrated with operating diagrams, performance charts and installation photographs.

Centrifugal Fans

The New York Blower Company has recently published its new capacity tables for type ME centrifugal fans—both slow-speed and high-speed wheels. The tables are in the company's conventional $8^1/_2 \times 11$-in. sectional catalog form. The slow-speed tables and engineering notes comprise 16 pages and the high-speed tables 24 pages. These publications conform to the program of industry standardization for sizes and construction as adopted by the National Association of Fan Manufacturers at its Annual Meeting in Chicago in April of this year. They are available for those who are interested.

Circuit Breakers

A 12-page illustrated booklet describing "De-Ion Grid" type "O" oil circuit breakers, designed for indoor service for voltages from 15,000 to 34,000 and for interrupting capacities from 500,000 to 2,500,000 kva, has been announced by the Westinghouse Electric and Manufacturing Co. Distinctive features are simply described in non-technical language. Cutaway sketches show the principal design features with supplementary photographs aiding their description and explanation. A table of rating data, shipping weights, oil requirements and dimensions make up the last several pages of the booklet.

Deaerating Heater

The 12-page illustrated bulletin, No. 2357 which The Permutit Company recently published, briefly relates the history of the development of deaerating heaters, presents the causes of corrosion of boilers and piping and methods for preventing such corrosion. It describes and illustrates the Permutit deaerating heater which is said to remove all oxygen and free CO_2 from the water. This heater does not require any trays for deaeration but sprays the water from non-corrodible spray valves through steam, which heats the water within 3 or 4 deg of steam temperature. This preheated water then passes through the steam scrubber from which, it is reported, the last traces of oxygen and free CO_2 are removed.

Expansion Joints

The Yarnall-Waring Co. has revised its 16-page bulletin on Yarway Gun-Pakt Expansion Joints. The bulletin contains descriptive matter, diagrams, pictures of installations, weights, dimensions, prices and a table of linear expansion of steel pipe lines. There is also included a page covering "Gland-Pakt" expansion joints.

Gage Valves

A compact, illustrated bulletin, Number 401, covering its line of boiler water gage valves, has recently been released by the Reliance Gauge Column Co. It contains descriptions of valves for low- and high-pressure equipment and certain boiler gage specialties.

Motors

The General Electric Co. has issued 3 bulletins, numbers GEA 1412B, 1368D and 3223, covering solid-shaft and hollow-shaft induction motors and single-phase motors, respectively. These are all of the vertical type and of the shielded (dripproof) construction, and range in capacity from 1 to 5 hp for the single-phase motors and from 1 to 200 hp and larger for both types of induction motors.

Oil Pumps

The DeLaval Steam Turbine Company has issued a 12-page bulletin describing its line of IMO oil pumps, series A-32. These pumps are built in capacities above 30 gpm for pressures up to 500 lb per sq in. The bulletin is fully illustrated and contains descriptive material covering construction features and advantages of the IMO design.

Protective Coatings

The Dampney Company of America has revised its bulletin No. 1290 which describes Apexior Number 1, a protective coating for hot wet metal surfaces, and Apexior Number 3 for cold wet or hot dry metal surfaces. The bulletin contains information as to methods of application, extent of covering, size of containers, equipment for application and prices.

Rotary Pumps

Fairbanks, Morse and Co. has published a 12-page bulletin describing its line of rotary pumps. There are descriptions, illustrations and tables covering the various capacity pumping units of single, multiple, "Builtogether" and sanitary types, as well as engineering data.

Rubber Goods

Goodrich Mechanical Rubber Goods is the title of a new 24-page booklet published by B. F. Goodrich Co. It serves the threefold purpose of a condensed catalog, engineering data guide and guide to the selection of various products. Among the subjects covered are rubber transmission belting, cord conveyor belting, endless splicing, shock idler mountings, hose and fittings, packing, rubber mats, hard rubber sheets and pipe, rubber-lined tanks, pipes and acid drums, rubber paints, cements, putty and plastic compounds, vibration insulators, rubber tape and other products.

Steel Valves

Manning, Maxwell and Moore, Inc., announce the recent publication of a 40-page catalog, No. 5-7000, containing complete dimensions of all its types of valves and their material specifications. In addition there are pages reproducing in full the A.S.M.E. Service Rating Tables.

Temperature Regulators

Sarco Company, Inc., announces a new catalog, No. 52, covering self-operated temperature regulators for controlling flow of steam, gas, water or brine. Sixteen illustrated pages show several new types. A special feature is complete capacity tables for several different valve styles to meet control problems in connection with industrial process work, water heating, air conditioning, refrigeration, etc.

Thermocouples

An interesting 16-page bulletin, No. S2-2, illustrating and describing thermocouples, thermocouple wire, lead wire, insulators and protecting tubes has been issued by Wheelco Instruments Co. It contains recommendations for selection of the proper material for various temperatures and duties, kinds of media and types of atmosphere.

Traps

"Nicholson Steam Traps" is the title of a 17-page catalog, number 420, recently published by W. H. Nicholson and Co. It describes steam traps of thermostatic, expansion, weight-operated and piston-operated types, and gives a list of recommended uses and piping diagrams.

Slag Removal . . .

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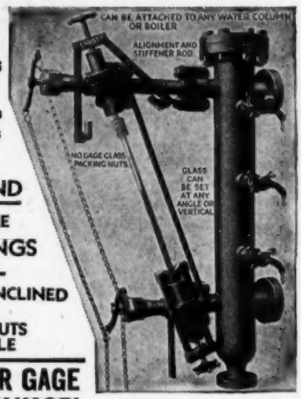
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